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Item Unique Identification (IUID) marking for a littoral combat ship (LCS) class mission module (MM) at the mission package support facility (MPSF): implementation analysis and development of optimal marking procedures

Goodman, William K.; Rodriguez, Roland G.; Infante, Isaia Benette E.

Monterey, California. Naval Postgraduate School

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NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

MBA PROFESSIONAL REPORT

Item Unique Identification (IUID) Marking for a Littoral Combat Ship (LCS) Class Mission Module (MM) at the Mission Package Support Facility (MPSF): Implementation Analysis and Development of Optimal Marking Procedures

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By: William K. Goodman,
Isaia Benette E. Infante, and
Roland G. Rodriguez

June 2010

Advisors: Geraldo Ferrer,
Douglas Brinkley

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William K. Goodman, Lieutenant Commander, United States Navy
Isaia Benette E. Infante, Lieutenant, United States Navy
Roland G. Rodriguez, Lieutenant Commander, United States Navy

Submitted in partial fulfillment of the requirements for the degree of

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from the

NAVAL POSTGRADUATE SCHOOL
June 2010

Authors: ____
William K. Goodman

____
Isaia Benette E. Infante

____
Roland G. Rodriguez

Approved by: ____
Geraldo Ferrer, Co-Lead Advisor

____
Douglas Brinkley, Co-Lead Advisor

____
William R. Gates, Dean
Graduate School of Business and Public Policy

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ABSTRACT

The purpose of this MBA project is to implement an effective solution to the DoD’s mandatory January 2004 IUID policy for LCS MPs at the Port Hueneme MPSF. Our methodology was to analyze the item marking process to determine the optimal marking procedure for items that bypassed the MPSF. Logical Decisions® for Windows was utilized to determine the best course of action with regard to cost, crew burden, compliance achievement, and reduced mistakes. It was determined that, among five possible courses of action, waiting for a maintenance availability was the optimal solution.

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LIST OF ACRONYMS AND ABBREVIATIONS

1D	One-Dimensional
2D	Two-Dimensional
ADCS	Automated Data Capture System
AES	Applied Enterprise Solutions
AI	Application Identifier
AICS	Automated Inventory Control System
ASCII	American Standard Code for Information Interchange
ASW	Anti-Submarine Warfare
AT&L	Acquisition, Technology, and Logistics
AT/FP	Antiterrorism and Force Protection
C5I	Command and Control, Communications, Computers, Combat Systems and Intelligence
CAGE	Commercial and Government Entity Code
CM	Configuration Management
CSG	Carrier Strike Group
CTP	Common Tactical Picture
DFARS	Defense Federal Acquisition Regulation Supplement
DI	Data Identifier
DoD	Department of Defense
DPM	Direct Part Marking
DUNS	Data Universal Numbering System
EAN.UCC	European Article Numbering—Uniform Code Council
ECC	Encoded Pattern Redundancy
EO	Electro-Optical
EOT	End of Transmission
G/S	Group Separator
GAO	Government Accountability Office
GCSS	Global Combat Support System
IAC	Issuing Agency Code
ID Matrix	International Data Matrix
IEC	International Electrotechnical Commission
ILS	Integrated Logistics Support
IR	Infrared
ISO	International Organization for Standardization
ISR	Intelligence, Surveillance, and Reconnaissance
IUID	Item Unique Identification

LCS	Littoral Combat Ship
LCS CLASSRON	Littoral Combat Ship Class Squadron
LDW	Logical Decisions® for Windows
MCM	Mine Countermeasures
MFOM	Maintenance Figure of Merit
MIL-STD	Military Standard
MIO	Maritime Intercept Operations
MM	Mission Module
MP	Mission Package
MPSF	Mission Package Support Facility
MTBF	Mean Time Between Failures
NBVC	Naval Base Ventura County
NLOS-LS	Non Line of Sight-Launching System
NSWC PHD	Naval Surface Warfare Center, Port Hueneme Division
OEM	Original Equipment Manufacturer
PEO LMW	Program Executive Officer—Littoral and Mine Warfare
RFID	Radio Frequency Identification
SIPRNET	Secret Internet Protocol Router Network
SLOC	Sea Lines of Communication
SOF	Special Operating Forces
SUW	Surface Warfare
TAV	Total Asset Visibility
UAV	Unmanned Vehicles
UID	Unique Identification
UII	Unique Item Identifier
UPC	Universal Product Code
USD AT&L	Under Secretary of Defense for Acquisition, Technology, and Logistics
VIN	Vehicle Identification Number
VTAV	Vertical Takeoff Air Vehicle

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I. INTRODUCTION

A. BACKGROUND

The goal of achieving total asset visibility (TAV) in the Department of Defense (DoD) supply chain has challenged the DoD since its inception. Despite setbacks in TAV goal achievement, the DoD continues to pursue the need to account for all of its inventory due to the costly consequences. A Government Accountability Office (GAO) report on defense inventory provides an example: "[a]s Operation Iraqi Freedom began, a number of asset visibility weaknesses contributed to a $1.2 billion discrepancy between the material shipped to Army activities in the Iraqi theater and the material acknowledged as received" (GAO, 2004). With three TAV implementation plans and unmet target completion dates of 1980, 1995, and 2004, the TAV expected date of completion has been moved to 2010 (GAO, 2004).

After the revisions to the implementation plans, TAV's purpose was to eliminate the acquisition of redundant inventory and provide updated information on inventory in the supply-chain pipeline by knowing its status (location, amount, etc.). After making this information available, there remains one critical requirement for the DoD to achieve its TAV goal: the ability to share these data across multiple levels in the supply chain, as well as between the services (GAO, 2004). A tool that the DoD is implementing in order to make up for this shortcoming and help achieve TAV is Item Unique Identification (IUID).

IUID is a system of marking items with encoded globally unique identifiers that have unambiguous machine-readable data elements (DoD DPAP, 2006). This makes it possible to identify materiel assets in the DoD supply chain specifically and uniquely. An individual part can be specifically identified as unique utilizing IUID, as opposed to a bin of many of the same parts that all have the same identifying information encoded on their barcodes. In addition, IUID contains a registry that stores several key aspects of materiel information that is not service specific, achieving one of the key requirements needed to attain TAV.

On July 29, 2003, Michael Wynne, the acting Under Secretary of Defense for Acquisition, Technology, and Logistics (USD AT&L), published a policy memorandum establishing the DoD requirement to implement IUID on all qualifying solicitations issued on or after January 1, 2004 (USD, 2003). As a result, any item that met certain requirements was supposed to have an IUID tag attached to key components of the equipment. One of the ships developed after the regulation was passed was the Littoral Combat Ship.

The Littoral Combat Ship (LCS) is one of the newest Navy platforms being acquired today. Boasting speeds of over 40 knots, the LCS takes advantage of a concept new to United States Navy ships—mission modularity. Combat systems are usually built into the structure of a ship, but the LCS utilizes modular mission packages that can be removed and replaced when the threat, environment, or mission changes. Mission packages for the LCS include anti-submarine warfare, anti-surface warfare, and mine warfare (Pike, 2008). With three main mission packages, the management of these systems has spurred the development of a facility to meet the maintenance and overall life-cycle management of these systems—the Mission Package Support Facility.

The Mission Package Support Facility (MPSF) is a storage, maintenance, and intermediate maintenance-capable site for the mission modules of the LCS. In addition, inventory management of the mission modules is a key responsibility of the MPSF. Knowing full well the need to be in compliance with the DoD IUID regulation, the MPSF, under the leadership of PMS 420, has developed an IUID plan, specific to the mission modules. The goal of the plan is to:

- Be compliant with the Department of Defense UID policy for solicitations issued after January 1, 2004
- Implement an effective solution for UID of PMS 420 procured items
- Implement an automated solution
- Minimize lifecycle sustainment costs (Littoral Combat Ship (LCS) Mission Modules (MMs) Unique Identification (UID) Plan).

However, accomplishing these objectives has provided some unique problems due to the nature of the mission modules and that of the LCS.

With the modularity of its weapons systems, the LCS presents unique challenges that have not been dealt with before. Personnel at the MPSF have identified the need to meet DoD's IUID regulation and have identified an important task for ensuring compliance with the IUID regulation. There are instances when key pieces of equipment are not going to have an IUID tag on an item, and the MPSF wants to ensure that the amount of time the equipment is without a tag is minimized. This is not only to be in compliance with the regulation, but also to provide the necessary management to keep track of items that require tracking. The importance of ensuring that a tag is placed on these items is a critical issue for MPSF mission module managers.

B. PURPOSE

The purpose of this research is to determine the instances in which an item in the inventory pipeline of the LCS mission modules will have a component that does not have an IUID tag, but requires the tag. In addition, our team hopes to come up with viable solutions for tagging such components at the earliest point possible.

C. METHODOLOGY

The methodology implemented in this research includes the following:

1. Review material pertinent to IUID use and regulations.
2. Conduct an MPSF site visit to better acquaint the research team with processes involved and the unique challenges posed by the mission modules.
3. Review operations management material to understand how best to analyze the data attained from the MPSF site visit.
4. Brainstorm possible solutions that the MPSF can implement to ensure that equipment requiring an IUID is tagged.
5. Analyze data provided by MPSF and give cost data to justify the implementation of certain courses of action.
6. Provide a summary and recommendations to the MPSF that will help in augmenting their current IUID implementation plan.
7. Analyze one of the mission modules and use this analysis as a means for designing a similar plan to apply to the other mission modules.

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II. ITEM UNIQUE IDENTIFICATION

A. INTRODUCTION

The Department of Defense (DoD) recognized that it required an aggressive Automated Inventory Control System (AICS) as early as 1998, when the Government Accountability Office (GAO) discovered issues with the DoD's inventory management. Despite having an inventory that exceeded its requirements, the DoD still lacked essential spare parts due to insufficient asset visibility and ineffective asset accountability. Even though the DoD has many asset-management systems, there is no universally accepted method of identification that allows visibility of items across AICSs and throughout their lifecycles. Before the DoD could utilize a more capable AICS, it would need to implement an Automated Data Capture System (ADCS) solution that could support the advanced AICS. Since the performance of the AICS would be determined by the information it received, the ADCS would need to be able to identify tangible assets individually with a method that was globally unique and unambiguous. Additionally, the ADCS would need to ensure data integrity and data quality throughout the life of an item. Furthermore, the AICS would need to support a wide array of business applications and users (Clarion, 2009). The DoD's solution to this deficiency is called IUID.

IUID is a system of marking items with encoded globally unique identifiers that have unambiguous machine-readable data elements (DoD DPAP, 2006). With ADCS, an IUID mark can be verified for integrity and quality and then be permanently affixed to the item. IUID is capable of distinguishing one item from all other items and enables DoD to track identical items throughout their lifecycle. The ability to accurately track the item over its lifecycle and store that information in a registry enhances operational readiness and efficiency by greatly reducing the time required for acquisition, repair, and deployment of items (Clarion, 2009). The DoD selected the IUID mark for its worldwide AICS and ADCS compatibility. By using a unique and universally accepted method of identifying an item, IUID enables a common language between multiple industries and governments for asset visibility and reliable accountability (USD, 2005a).

B. IUID HISTORY AND BACKGROUND

In order to understand the utility of IUID, it is necessary to know how the technology evolved. Barcodes, as we know them today, came from a marrying of efforts from academia, the railroad industry, and the grocery industry. These efforts spanned two and a half decades before the most popular version of the technology, the Universal Product Code (UPC), was adopted as the commercially successful industry standard (Seideman, 2009).

1. Barcode Design

The original barcode concept was a dual effort first introduced in 1948 by Norman Woodland, a graduate student and teacher at Drexel Institute of Technology in Philadelphia, and Bernard Silver, a graduate student at the same institution (Harris, Locklar, & Wright, 2008). Woodland was intrigued by Morse code and the technology adapted from optical soundtracks in movies. He was inspired to apply similar technologies to creating a barcode after he was approached by Silver. Silver had overheard a local food chain president ask Drexel's dean to have research conducted on a method to automatically capture information from products while the items were being sold at the checkout counter. The dean rejected the request, however, and when Silver mentioned this to Woodland they decided to take on the project. Woodland became so fascinated with the project that he eventually quit his teaching job in order to dedicate all of his time to research and development (Seideman, 2009).

Originally, Woodland and Silver developed two barcode designs. In a patent application they filed on October 20, 1949 as a "Classifying Apparatus Method," they detailed linear and bull's-eye patterns (Seideman, 2009). The bull's-eye pattern, as the name implies, was made up of a series of concentric circles. Woodland favored this design since it could be read by early scanners from any direction. However, Silver was unhappy with some of its properties, so he continued to investigate what form of the code would be most reliable.

Also described in the patent application were the mechanical and electronic systems required to read the code. Although Woodland and Silver had developed the barcode, they could not come up with an affordable or practical way to read the code. Any grocery store wishing to implement the barcodes would require the installation of the scanning equipment. At the time, their scanner was the size of a desk, and the computer that would be required to record data from the codes was equal in size to the grocery store's frozen food section. Scanners would not become a feasible option until over a decade later, when more-affordable lasers and microchips were developed. Even though Woodland and Silver were issued the patent three years after filing on October 7, 1952, their contribution to the technology's progress had been halted due to the issues with reading the code (Seideman, 2009). Understanding the utility of the technology, Philco purchased the patent in 1962 and then sold it later that year to RCA.

2. Barcode Scanner

The next contribution to barcode technology came in the early 1960s from a Sylvania Corporation employee named David Collins. While working on a project that involved the identification of railroad cars, he designed a coded label that could be scanned with different technology than that used on barcodes. His coding system was so effective that it became the railroad industry standard in 1967. However, like Woodland and Silver's system, the scanners were expensive and Sylvania was unwilling to move the technology beyond the railroad industry. Seeing the applicability of the technology to other industries and failing to convince Sylvania of its profit potential, Collins quit his job and co-founded Computer Identics Corporation. In the mid 1960s, technological advancements made lasers more affordable, and Computer Identics Corporation was able to develop barcode scanners that were more practical. In order to demonstrate the feasibility of the scanners, Collins implemented two of the first true barcode-scanning systems in 1969 at an automotive manufacturing plant and a distribution center. In doing so, he successfully demonstrated the technology's potential in an industrial setting (Seideman, 2009).

3. The UPC

The next big movement in barcode technology came from the grocery industry. In 1971, RCA, which had now owned Woodland and Silver's patent for almost ten years, demonstrated a bull's-eye barcode system at a grocery industry meeting and gained much attention for their efforts. IBM executives at that meeting noticed RCA's success and wanted in on this huge potential market. A marketing specialist at IBM remembered that the barcode's inventor, Norman Woodland, had been working at by IBM since 1951. Woodland had been trying to convince the company to pursue the technology ever since he began working there. Now, finally, they were coming to him for advice. Woodland was transferred and assigned to the project, where he played a key role in the development of the UPC, which was adopted as the industry barcode standard on April 3, 1973 (Seideman, 2009).

The standardization of the UPC was a major milestone because it enabled any product with the code to be scanned and recognized by any system that had the product registered. Before the UPC was adopted, each product may have been marked with a different type of code. For example, one product may have been marked with a linear barcode and another with a bull's-eye code. Since scanning systems could recognize only one code or the other, if a grocery store's checkout counter wanted to identify both types of codes, it would need two scanning systems, one for each code. The UPC established a level of standardization that revolutionized the grocery industry. The savings through inventory accuracy and profits from processing speed would pay for the systems required in a couple of years and save the grocery industry hundreds of millions a year thereafter (Seideman, 2009).

4. One-Dimensional Barcode Limitations

As the use and success of barcodes in the grocery industry became more widespread, other industries began to recognize the utility of barcode technology. Its application to a wider audience required barcodes to contain more data characters than the ten-character limit of conventional linear 1D barcodes. The most sophisticated 1D

barcode symbology,[1] Code 128 (Figure 1), can encode a combination of only ten total numbers, zero through nine, and upper- and lower-case alphabet characters (Allen, 2008). Size is also an important limiting factor. 1D barcodes, such as “Interleaved 2 from 5” and Code 128, can be half the size of standard barcodes (Figure 1). However, these types can encode only up to ten numeric characters. Due to reduced data capacity, 1D barcodes are typically used as database keys. The codes contained within the barcode are merely a key that enables the associated information to be retrieved from a database (Obellos, Colleran, & Lookabill, 2007).

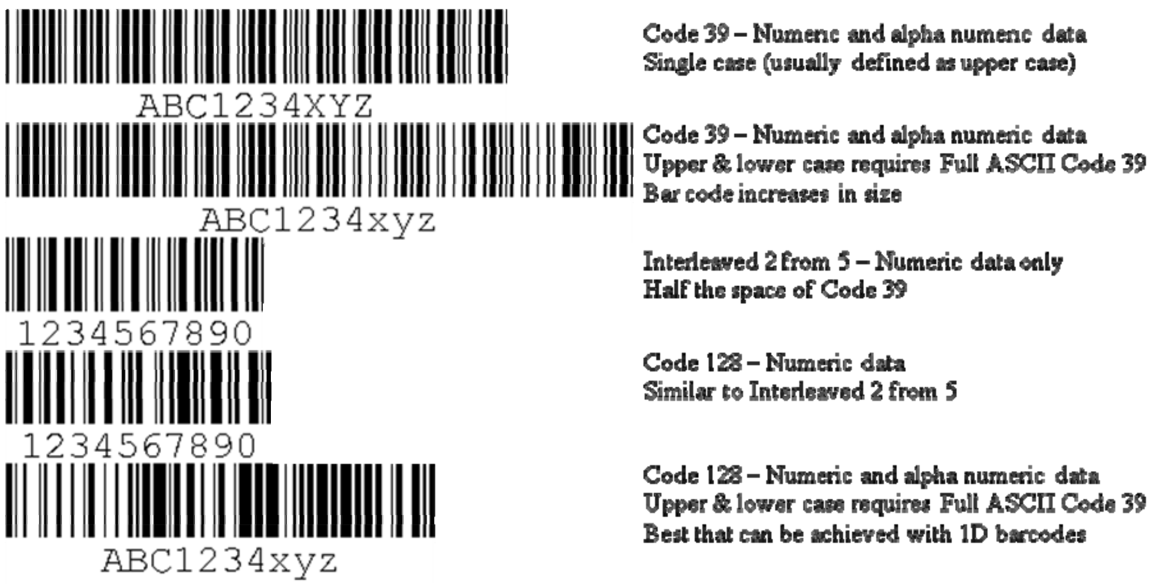

Figure 1. 10 Character 1D Barcode Types (From: Allen, 2009)

5. Evolution from One Dimension to Two Dimensions

The need for a barcode capable of coding more data without increasing its footprint on the item was answered in 1988 by David Allais, who was working at Intermec Corporation (Adams, 2009). Allais had created the first 2D barcode, Code 49, which was capable of performing as a portable database rather than as a database key.

[1] Barcode symbology describes the language that is derived from the characters within a barcode. These characters are represented by the varying heights and widths of black bars and white spaces within a barcode.

Greater amounts of information about an individual item, including its history, could now be encoded in the item’s barcode. The Code 49 symbology utilizes two to four rows of 1D barcodes that are stacked on top of each other (Obellos et al., 2007). The 2D configuration differs from the 1D design since the width and height of the black bars and white spaces are now measured. Since Code 49 was introduced, many other designs have been developed or redesigned by either stacking 1D barcodes, known as stacked symbology, or placing them one after the other in series, known as multi-row code. 2D barcodes can also utilize a matrix in which the data code is based on the relative position of black and white modules within the matrix (Adams, 2009). These 2D matrix barcodes all have the advantages of containing a far greater number of characters than 1D barcodes while maintaining a very small footprint on the item (Figure 2). The ability to encode so many characters in these evolved barcodes gave rise to the term “unique identification,” or UID, since it was now possible to identify individual items apart from other items of the same type (USD, 2005a).[2]

Data Matrix (3,116 characters)   PDF417 (2,000 characters)   MaxiCode (93 characters)   QR Code (1,500 characters)

Figure 2. 2D Barcodes (From: Barcode Symbologies, 2009)

6. Data Matrix ECC200

In the 1990s, the 2D Data Matrix ECC 200 matrix barcode was invented through a joint effort between International Data Matrix, Incorporated (ID Matrix) and the National Aeronautics and Space Administration (Cherniavsky, 1999; Harris & Worrell,

[2] UID is a broad term commonly used to describe any complete barcoding system or individual elements of that system.

2008).[3] In July 2003, the DoD IUID policy selected the Data Matrix ECC200 as the barcode of choice for the DoD. This decision was based on the barcode's worldwide acceptance and compatibility with nearly all part-marking techniques. This compatibility is based on the barcode's use of the International Organization for Standardization and International Electrotechnical Commission (ISO/IEC) 15434 syntax. This data format, an information security standard for marking items, is used across many business sectors. In order to ensure the DoD's use of this syntax, it has been detailed as a requirement in Military Standard-130N (MIL-STD-130N) (USD, 2005a). Other unique properties that made it the perfect candidate included the symbols' encoded pattern redundancy or ECC, which allows it to be read even when partially damaged. Also, like other 2D symbols, it can be scaled down to fit on very small items where space is a premium (Harris & Worrell, 2008).

7. UII

The use of the 2D Data Matrix ECC200 barcode is widespread among non-DoD organizations. However, a distinction must be made between the data elements encoded within those matrix barcodes and those encoded within the matrix barcode used by the DoD. The DoD's Data Matrix is encoded with a UII. This set of data elements is globally unique, unambiguous, and permanent for the life of the item (Newman, 2009). UII is the key that ensures data integrity and enables the DoD to reliably locate, control and value marked items (USD, 2006).

For the UII to be globally unique, unambiguous, and permanent for the life of the item, it must consist of a format code, data identifiers, an enterprise identifier, and a serial number (Figure 3). A part number may be included, depending on which data construct is used. When creating a UII, the creating activity or enterprise must choose one of two available constructs. These constructs are aptly named construct 1 and construct 2.

[3] ID Matrix was merged into Robotic Vision System, Incorporated's Acuity CiMatrix Division, which Siemens Corporation acquired in October, 2005. Siemens was then acquired by Microscan in September, 2008.

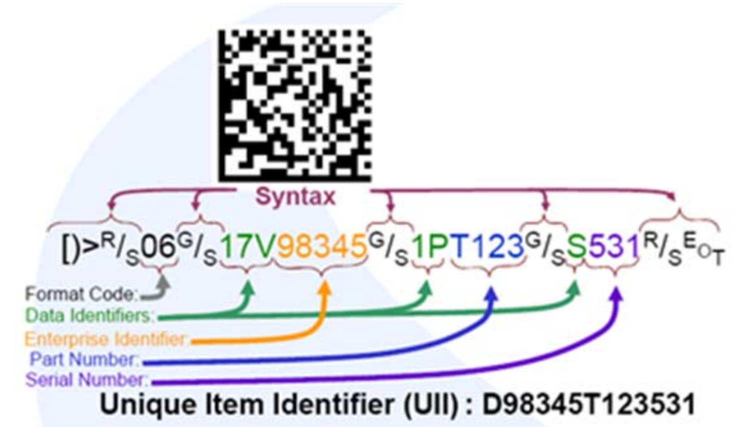

Figure 3. UII Composition (From: MacDougall, 2008)

Construct 1 is used for serialized items. These are items that are assigned unique and sequential serial numbers within a particular enterprise. Construct 1 includes the data elements of the serial number and enterprise identifier (Figure 4) (DoD DPAP, 2006, p. 12).[4] For construct 1, the enterprise identifier is referred to as the Commercial and Government Entity Code (CAGE). Construct 1 is more advantageous since it uses fewer characters, has a smaller footprint, and is more precise (Andresen, 2006).

Construct 2 is used for items serialized within a part type. These are items that have serial numbers that are not unique within a particular enterprise and must include the associated part number's data elements in order to be unique. Construct 2 includes the data elements of the serial number, original part number, and enterprise identifier (Figure 4). For construct 2, the enterprise identifier is referred to as the Data Universal Numbering System (DUNS). Since the original part number is used in construct 2, the item's current part number is not required to build the IUID. This design enables the part to be rebuilt, modified, and upgraded without affecting the IUID (Andresen, 2006).

In addition to including either construct 1 or construct 2, the UII must include the appropriate semantics in order to be compliant with the ISO/IEC 15434 syntax. These semantics are non-printable characters from the American Standard Code for Information Interchange (ASCII) character set. In Figure 3, "R/S" is a record separator or block-mode

[4] An enterprise identifier is a unique code assigned to an enterprise by a registered issuing agency.

terminator when used in conjunction with "EOT" (End of Transmission) and distinguishes the UII from other data elements encoded within the Data Matrix ECC200. Also in Figure 3, "G/S" represents the group separator character and is what separates the individual codes, identifiers, and numbers from one another within each UII. Although the Data Matrix is capable of encoding up to 3,116 characters from the entire 256-byte ASCII character set, the UII construct can have no more than 50 of those characters. These characters can only be capital letters A through Z, numbers 0 through 9, forward slashes (/), and hyphens (-) (MacDougall, 2008).

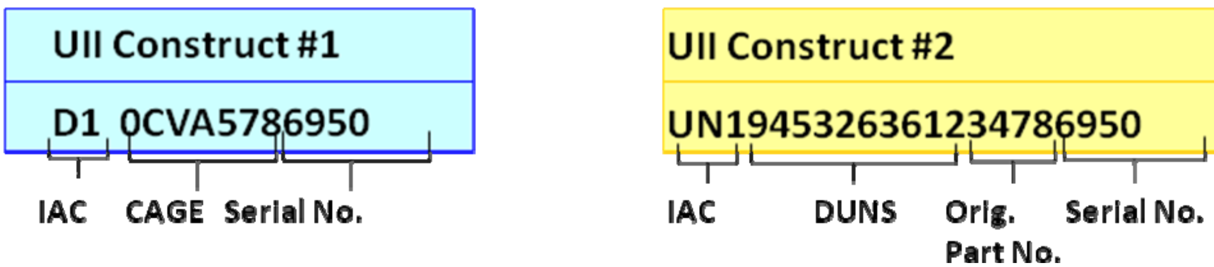

Figure 4. Construct #1 and #2 Composition[5] (Andresen, 2006; DoD DPAP, 2006) (From: Newman, 2009)

8. UID and IUID

It is the inclusion of the UII by the DoD that distinguishes IUID from UID. In the overwhelming majority of cases, IUID is the term used to describe only the DoD's Data Matrix ECC200 barcoding system. However, in some cases, the DoD may recognize a commercial enterprise identifier as equivalent to an IUID enterprise identifier. If the commercial identifier uniquely identifies an individual item that is within the enterprise identifier, product, or part number and has an existing Data Identifier (DI) or Application Identifier (AI) listed in American National Standards Institute MH10.8.2, DI and AI Standard, then the commercial enterprise identifier can be used in place of the DoD enterprise identifier within the UII. Once these criteria are met, the commercial UID will be equivalent to IUID. At this time, the only four commercial identifiers recognized by

[5] Issuing Agency Code (IAC), derived from the data qualifier for the enterprise identifier (CAGE or DUNS), represents the agency that issued the enterprise identifier and is added by the IUID AIS to create the complete concatenated IUID code.

the DoD as IUID-equivalent are the European Article Numbering—Uniform Code Council (EAN.UCC) Global Individual Asset Identifier, the EAN.UCC Global Returnable Asset Identifier, the ISO Vehicle Identification Number, and the Electronic Serial Number (DoD DPAP, 2006).

C. MARKING

MIL-STD-130N details all IUID marking requirements and is the solitary IUID marking authority (USD, 2007). In accordance with this standard, it is the Program Manager's responsibility to decide which method of marking to use on a particular item. Once the method and type of mark are determined and the Data Matrix is created, an electronic scanning device called a verifier is used to verify that the encoded data are compliant with MIL-STD-130N. The accuracy of the data must also be validated with the verifier to ensure that it is readable and compliant with the international barcode quality specification, ISO/IEC 15415. After these procedures are accomplished, the Data Matrix mark can be placed on the item in accordance with the standard.

When deciding on a method of marking, the program manager must carefully consider factors regarding the item and the manufacturer. In order for the Data Matrix to remain with the item for its lifecycle, an accurate analysis of harsh or protected operating environments must be made. Characteristics of the item's durability or fragility must be determined to ensure that the type of mark is compatible. Rigorous or frequent maintenance procedures will require a mark able to withstand the stress. The mark's potential to inhibit the performance of the item must also be considered. The method of marking can also be influenced by the manufacturer's constraints regarding methods, procedures, and technical knowledge of marking parts (USD, 2005a).

Currently, the three methods of marking an item with an IUID Data Matrix are label printing, data plates, and Direct Part Marking (DPM). Virtually all item-marking techniques used by manufactures are compatible with at least one of these techniques, so any requirement to generate marks would not change their existing process. If, for some reason, a manufacture had no current method of marking items, a separate marking vendor could easily be contracted (USD, 2005a).

1. Label Printing

Label-printing methods, such as those that utilize tape and ink jet labels are sufficient to satisfy the majority of IUID marking requirements (Figure 5). Since these items are generally operated and maintained in a protected environment, as long as the label’s adhesive adheres to the item, the mark will remain affixed throughout its life-cycle. Label printing is the least expensive and easiest marking method in terms of time, labor, and cost. If an item will be subjected to high temperatures or other extreme conditions, a more robust method of marking will be required, such as data plates or DPM (Blakiston, Punzel, & Jennings, 2008).

Tape Label Ink Jet

Figure 5. Label Printing (From: Newman, 2009)

2. Data Plates

Data Plates utilize a plastic or metal plate that can be fastened to the item with screws, rivets, or industrial-strength adhesives (Figure 6). Although considerably more expensive than labels in terms of time, labor, and cost, data plates are able to withstand much harsher conditions. However, the rigidity of data plates makes them ineffective in marking oddly-shaped items.

Metal Plates

Figure 6. Data Plate (From: Newman, 2009)

3. DPM

If oddly-shaped items are subject to extreme conditions, DPM's durability and space efficiency make it a viable marking alternative (Blakiston et al., 2008). DPM embeds the mark directly into the item, where it remains for the item's life. Types of DPM include dot peen, electro chemical etch, and laser etching (Figure 7). Since these methods have the potential to adversely affect the integrity of the item's structure, careful consideration must be made regarding the item's composition and structural tolerances. Laser etching is preferred over dot peen and electro chemical etch since the marking process is much faster. A drawback to DPM, as opposed to label printing and data plates, is that a mistake will compromise the entire item rather than just a cheap label or plate (Blakiston et al., 2008).

Figure 7. DPM (From: Newman, 2009)

D. SCANNING

The unique patterns that make up the 2D Data Matrix ECC200 can be read by ADCS devices commonly referred to as scanners, readers, or imagers. These types of ADCS devices use two slightly different technologies. Laser scanners use a photodiode to measure the intensity of the light reflected off the bar code and back to the light source in the scanner. Since the dark stripes absorb light and the white spaces reflect light, the photodiode generates a voltage waveform from the reflected light that is an exact duplicate of the bar-and-space pattern in the barcode. The waveform is then decoded by the Data Matrix symbology utilizing algorithms programmed into the scanner (Obellos et al., 2007). The second method of Data Matrix reading utilizes a Charge Coupled Device

reader. This type of device uses a technology that differs from the laser scanner only in that it measures the ambient light emitted from the barcode and not the reflection of light from the scanner (Denso Wave, 2009). Unlike 1D scanners, 2D Data Matrix scanners are capable of reading a Data Matrix barcode from various angles and directions. Additionally, these scanners can be equipped to read 1D barcodes. This improves efficiency since only one ADCS device is required if both 1D and 2D barcodes are used (Obellos et al., 2007).

E. IUID REGISTRY

IUID data on DoD-procured items have little inherent value. Rather, the real value of these data lies in the access that commands have to the information. It is the DoD's IUID registry, maintained by the Defense Logistics Information Service, that enables this access. All created UIIs must be stored in the registry, which serves as the central repository for all submitted IUID information. This central repository reduces redundancy by alleviating the need for individual components within the DoD to maintain separate IUID storage systems. Individual components requesting information on an IUID item can access it from the registry through the Global Combat Support System (GCSS) (Figure 8). This information identifies what the item is, how and when it was acquired, its initial value, whether it is in the custody of contractors or the government, and how it is marked (USD, 2006). This degree of item visibility has established IUID as an integral component of the DoD's initiative to increase asset visibility.

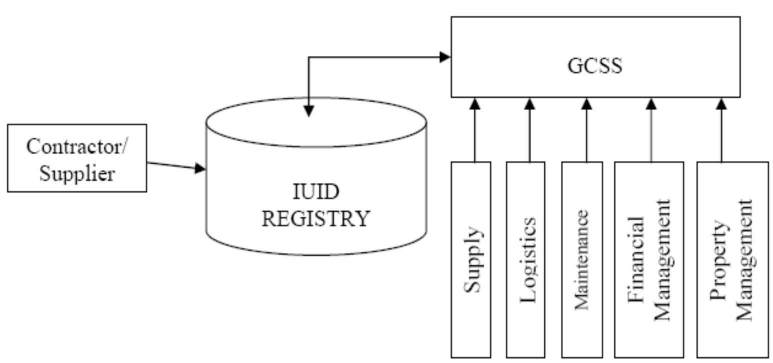

Figure 8. IUID Registry Access (From: Harris et al., 2008)

The responsibility for submitting IUIDs to the registry depends on the status of the item. Contractors or suppliers must register IUIDs for new items, while the individual DoD components are responsible for registering legacy items. Contractors or suppliers are able to submit IUID data electronically through the DoD's Wide Area Work Flow Receipt and Acceptance application (USD, 2007).

The specific information required by the registry includes data regarding the item's pedigree, valuation, accountability, and configuration (USD, 2006). Pedigree information refers to the item's original part number, serial number, shipping and delivery information, and acquisition contract information. Information on valuation includes the government's unit acquisition cost and any changes in value. Accountability information includes issuing-agency codes, enterprise identifiers, acceptance codes, and shipment dates. Data regarding configuration, such as embedded items, part number changes, and units of measure are required, as well (USD, 2006; Harris et al., 2008).

F. IUID POLICY

On July 29, 2003, Michael Wynne, the acting Under Secretary of Defense for Acquisition, Technology, and Logistics (USD AT&L), published a policy memorandum that established the mandatory DoD requirement to implement IUID on all qualifying solicitations issued on or after January 1, 2004 (USD, 2003). In accordance with the memorandum, contracts require IUID for items delivered to the government if: (1) the acquisition cost is $5,000 or more; (2) the item is serially managed, mission-essential or a controlled inventory piece of equipment or repairable item or a consumable item or material that requires permanent identification; (3) the item is a component of a delivered item, and the program manager has determined that unique identification is required; or (4) a UID or DoD-recognized UID equivalent is available (USD, 2003, p. 1) (Figure 9).

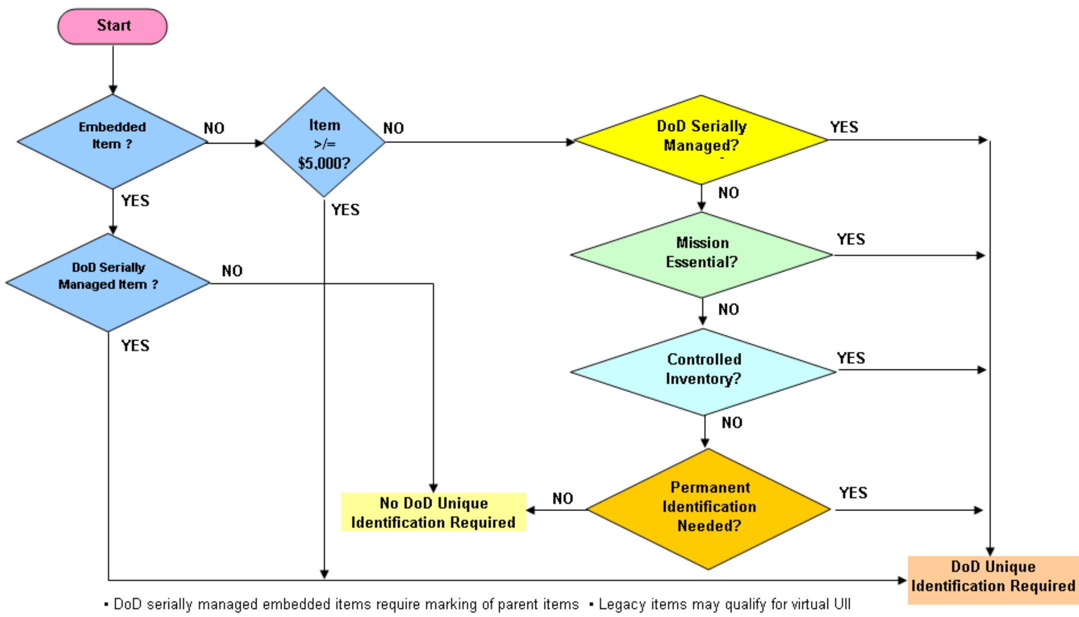

Figure 9. IUID Decision Tree (From: Newman, 2009)

On December 23, 2004, a policy update was distributed calling for IUID implementation to extend to legacy items in inventory and operational use. Additionally, items manufactured by organic DoD depots were included (USD, 2004). Another significant policy update, dated May 12, 2005, required the application of IUID to DoD property in the possession of contractors (USD, 2005b). The updates not only required individual units and contractors to obtain marking equipment, but they also had to decide which items should be marked (Figure 9).

The implementation of the IUID policy was divided into three phases. Phase I was the requirements phase, which established the IUID's data elements and was agreed upon and completed in April 2004. Phase II, the current phase, involves the implementation and migration planning for IUID. Despite a December 31, 2010 deadline to mark all components, implementation is taking longer than anticipated and this phase will most likely be extended. Once Phase II is completed Phase III, consisting of outreach and communication, will commence (Obellos et al., 2007).

G. CONCLUSION

The DoD's implementation of IUID was brought about by the GAO's concerns regarding insufficient asset visibility and ineffective asset accountability. The success of IUID in correcting these deficiencies is highly dependent upon the success of each step in the IUID implementation process. Errors involved in any element of UII creation, marking method, and registry submission will adversely impact IUID's effectiveness. The use of the Data Matrix ECC200 is clearly the right choice, based on its compatibility and durability characteristics. These properties increase the probability that the IUID mark will remain with the item throughout its lifecycle. Thus, the IUID data that it contains will enable cradle-to-grave asset tracking and provide the key the DoD needs to consistently control, locate, and value items.

III. LITTORAL COMBAT SHIP (LCS)

A. INTRODUCTION

The littoral combat ship concept was conceived on November 1, 2001, when the U.S. Navy declared that it was going to invest in a new generation of surface combatants under the Future Surface Combatant Program. This concept encompassed three new families of surface combatants: destroyers-DD(X), cruisers-CG(X), and littoral combat ships (LCS) (O'Rourke, 2010). In 2003, the U.S. Navy introduced the forerunner of the littoral combat ship (LCS) platform, named Sea Fighter. Sea Fighter is a prototype vessel that uses a unique hull type and is known throughout the LCS community as Fast Sea Frame (FSF-1).

B. LCS MODULAR DESIGN

The LCS is a new family of surface combatants (Naval Technology, 2010). This new class of ship is small, fast, highly maneuverable, and mission-focused. The LCS was designed primarily to navigate in littoral regions to combat the proliferation of asymmetric threats, diesel submarines, and small-boat attacks (Parsell, 2010a). In order for the LCS to effectively protect the coastal waters where it navigates, it must be able to perform one of the following three littoral missions when deployed: mine countermeasures warfare (MCM), anti-submarine warfare (ASW), and surface warfare (SUW) (Parsell, 2010b).

The LCS adopted a modular approach for successfully operating in the littorals. The basic feature of the LCS is its seaframe, with two basic seaframes currently in service: the semi-planing monohull and the trimaran hull. The modular seaframe is enhanced with the implementation of a mission package (MP). The three available MPs that correspond to the three littoral missions are mine countermeasures warfare (MCM), anti-submarine warfare (ASW), and surface warfare (SUW) (Good, 2009). Without an

MP, the LCS has an array of inherent capabilities that support Joint Operations Forces, Special Operations Forces, and maritime interception operations (Pike, 2008). Figure 10 illustrates the LCS design concept.

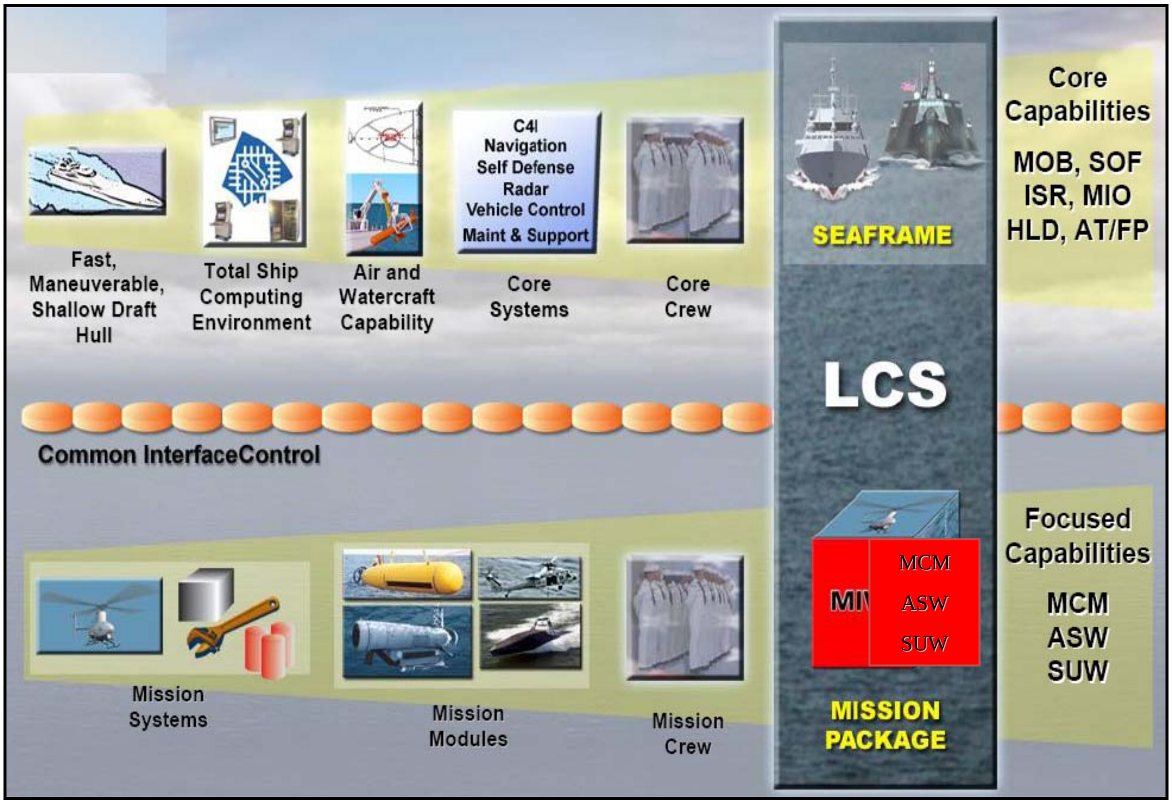

Figure 10. LCS Design Concept (From: Parsell, 2010a)

1. LCS Seaframe

The foundation of the LCS platform is the seaframe. The seaframe allows the LCS surface combatant to perform various missions through implementation of one of the MPs. Each mission package contains a mission system, support equipment, and crew.

Regardless of which MP the LCS has onboard, all seaframes share some common features: Command and Control, Communications, Computers, Combat Systems and Intelligence (C5I) infrastructure, an integrated tactical control system for unmanned

vehicles, utility resources, and shared self-defense capability (Naval Technology, 2010). The seaframe enables the LCS to support the Navy fleet in multiple roles by integrating different mission systems, mission modules, and personnel when deployed.

2. Mission Modules (MM) Capabilities

The LCS is the Navy's first surface combatant to be capability-centric versus platform-centric. With its modular approach, the LCS can easily swap out mission packages depending on its littoral mission. Although the LCS employs both minimal core self-defense systems and a small contingent of personnel within its seaframe, it is most effective when it implements an MP with mission systems, such as unmanned vehicles (UAV), helicopters, sensors, ordnance, support equipment, and personnel required to operate and manage these systems (PMS 420, 2009).

The LCS MMs are incorporated into the vessel through standard physical and digital interfaces provided by the ship's services: electrical power, compressed air, water, and C5I systems. The MMs provide the LCS with additional warfare capabilities and allow the LCS to meet a variety of primary and secondary missions while deployed in the littorals. In some cases, various aspects of the MMs are designed to overlap in their application and function (Pike, 2008).

3. LCS Missions

With the implementation of a specific mission package, each LCS will have a focused capability when deployed (Naval Technology, 2010). The primary mission of the LCS while operating in the littorals includes countering enemy lines, submarines, and fast-attack surface combatants (Marte & Szaba, 2007). Additionally, the LCS will have the capability to collect intelligence, conduct surveillance and reconnaissance functions, perform homeland defense operations, and carry out maritime, special operations, and logistics tasks.

The LCS is a multi-mission ship. It can navigate independently in littoral regions or deploy with a Carrier Strike Group (CSG). The LCS has the capability to complement the Aegis Fleet, operate with the U.S. Coast Guard and joint forces, as well as conduct underway replenishments while deployed for extended periods of time (Pike, 2008).

C. SELECTION OF TWO DEFENSE CONTRACTING TEAMS

In May 2004, the Department of Defense and U.S. Navy selected two military contracting firms to design and build both the LCS 1 (USS FREEDOM) and LCS 2 (USS INDEPENDENCE). These contracts were awarded to both Lockheed Martin (LCS 1) and General Dynamics (LCS 2). Currently, the Navy has plans to purchase 55 LCS seaframes and 64 mission packages: 16 ASW, 24 MCM, and 24 SUW (Marte & Szaba, 2009).

D. BODY TYPES OF THE LCS

Although the two LCS designs are unique, both satisfy the stringent technical and performance requirements set forth by the Navy and LCS Program Manager. The main difference between the two classes of LCS is their unique hulls. The LCS 1 class has a semi-planing monohull and the LCS 2 class has a trimaran hull. Similarities between the LCS 1 and 2 include their ability to achieve sprint speeds of over 40 knots; to launch and recover waterborne and airborne vehicles; and to have sufficient cargo and payload capability to support a small assault force (Naval Technology, 2010).

The two LCS classes also have similar ship characteristics. For instance, they have a full load displacement draft of ten feet, which allows the ship to navigate through shallow waters (Naval Technology, 2010). Each LCS class has the potential to reach a top speed of 50 knots and achieve 1,500 nautical miles while at sprint speed, and they both have an economical speed of 20 knots (PMS 420, 2009). Both classes were built with a flight deck and helicopter hangar and can launch and recover helicopters in sea state 5 and launch and recover waterborne vessels in sea state 4 (Naval Technology, 2010). Furthermore, common to both LCSs is the SUW mission module armament for the MK 50 30 mm naval gun weapon system. The MK 50 30mm is the weapon of choice for both the amphibious transport and LCS (PEO LMW, 2009). Other similarities between

the LCS 1 and 2 are their endurance and capability to hold 21 days of provisions, to replenish at sea, and to have a core crew complement between 15 and 50 personnel (Naval Technology, 2010).

1. LCS-1 (Lockheed Martin)

In December 2004, Lockheed Martin was awarded a contract to construct the U.S. Navy's first ever LCS ship, USS FREEDOM (LCS-1). FREEDOM's keel was laid in June 2005, and she was commissioned on 08 November 2008 in Veteran's Park, Milwaukee, WI and is now homeported in San Diego, CA.

a. Characteristics

The LCS 1 surface combatant was built with an advanced semi-planing steel monohull. This design uses a combination of both the Destriero's and the Jupiter's hull form, which allows it to perform effectively in shallow and deep waters and in high sea states (Navy Technology, 2010). With a length of 378 ft. and a beam of 57 ft., the LCS 1 vessel is able to navigate in littoral areas of 13 feet of water or greater. Additionally, the semi-planing monohull offers the LCS 1 better maneuverability. The following features allow the LCS 1 vessel to achieve or surpass all U.S. Navy maneuverability performance requirements:

- Full speed: within two minutes or less
- Stop: within three ship lengths at 30 knots
- Turn: achieve a 360 degrees turn at full speed within eight ship lengths or less (Pike, 2008)

b. Specifications

The LCS 1 also has specific key attributes that will allow for superior maneuverability and mission flexibility:

- Full load displacement: 3,000 metric tons
- Max speed: greater than 45 knots
- Core crew: fewer than 50 personnel

- Core Self-defense suite: 3D air search radar, BAE MK 110 57 mm gun, RIM-116 rolling airframe missile, 45 NLOS missiles, and decoy launching system (Pike, 2008)

The propulsion and electrical plant is comprised of two Rolls-Royce MT30 gas turbines, two Fairbanks Morse Colt-Pielstick diesel engines, four Rolls-Royce waterjets, and four Isotta Fraschini ship service diesel generators (Naval Technology, 2010). The LCS 1 also has automated stern doors, a stern ramp, side launch doors, and an overhead crane for launching and recovering waterborne vessels (Lockheed Martin LCS Team, 2009).

Additional innovative features that are critical to the LCS 1's optimal performance and mission success are shown in Figure 11.

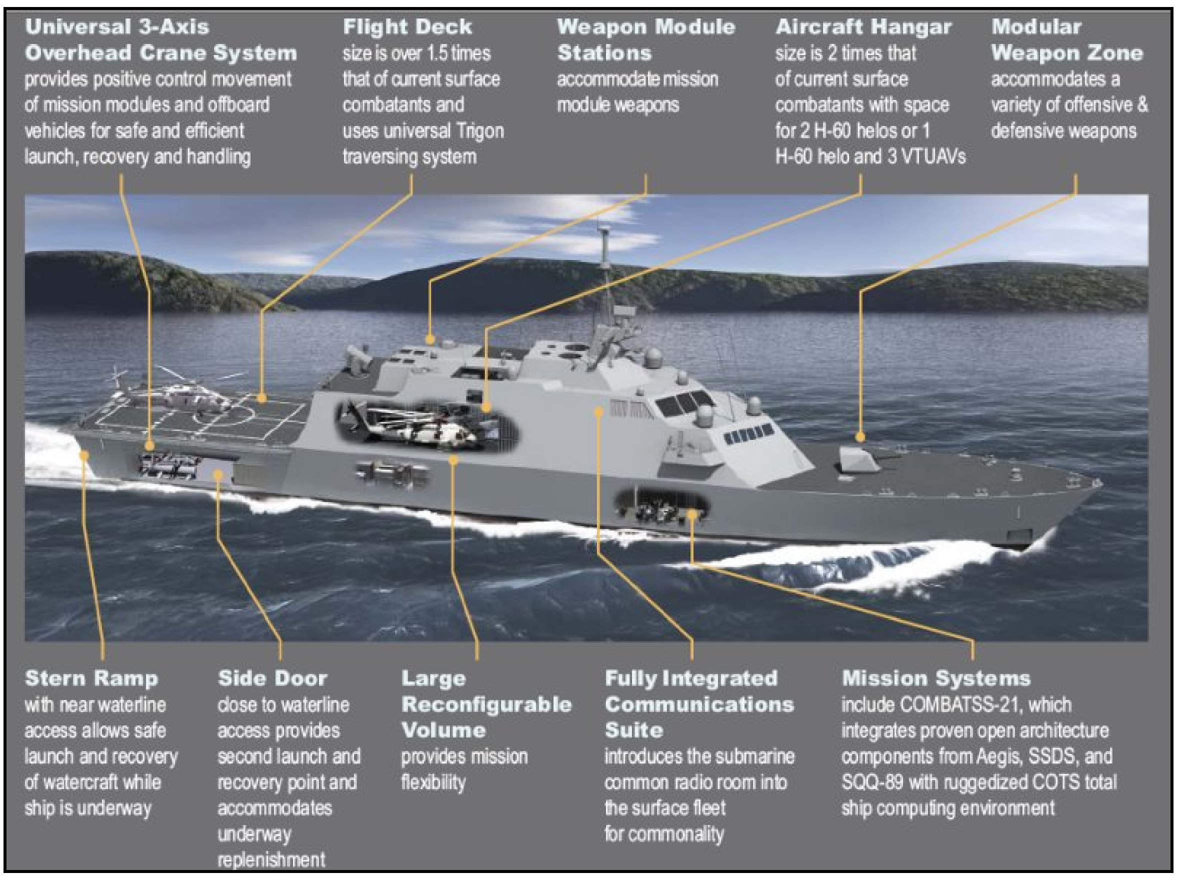

Figure 11. Semi-Planing Monohull (From: Lockheed Martin LCS Team, 2009)

2. LCS-2 (General Dynamics)

In October 2005, General Dynamics was awarded a contract to construct the U.S. Navy's second LCS ship, USS INDEPENDENCE (LCS-2). INDEPENDENCE's keel was laid in January 2006, and she was commissioned on January 16, 2010 in Mobile, Alabama and is now homeported in San Diego, CA.

a. Characteristics

The LCS 2 surface combatant was built with an aluminum trimaran hull. In addition to the trimaran hull, LCS 2 has two smaller hulls that facilitate navigation in rough seas and combat conditions. The trimaran concept allows the LCS 2 to perform well in a variety of sea-state conditions because of the aluminum structure and specific use of steel. With a length of 418 ft. and a beam of 103 ft., the LCS 2 surface combatant can navigate in littoral regions of 14 ft. of water or greater. The seaframe of LCS 2 is based on the Austal's design for the Benchijigua Express ferry (Naval Technology, 2010).

The following features allow the LCS 2 to achieve or surpass all U.S. Navy maneuverability performance requirements:

- Sustained high-speed performance
- Excellent agility and stability characteristics during repeated high-speed turns
- Stable ship's flight deck despite sea state 8 (Defense Update, 2010)

b. Specifications

The LCS 2 has specific key attributes that allow for superior maneuverability and mission flexibility:

- Full load displacement: 2,784 metric tons
- Top speed: greater than 44 knots
- Core crew: 40 personnel

- Core Self-defense suite: 3D air search radar, BAE MK 110 57 mm gun, 1 x Raytheon SeaRAM CIWS, 4 x .50-cal guns, and 4 x SRBOC decoy launchers for chaff and infrared decoys, and 1 x BAE Systems NULKA (Defense Update, 2010)

The propulsion and electrical plant for the LCS 2 is comprised of two MTU Friedrichshafen 20V diesel engines, two General Electric LM2500 gas turbines, four Wartsila waterjets, a retractable bow-mounted azimuth thruster, and four ship service diesel generators (Naval Technology, 2010). The LCS 2 also has an off-board vehicle launch and recovery system, starboard side mission bay access, and a mission bay lift (General Dynamics LCS Team, 2009).

Additional innovative features that are critical to LCS 2 optimal performance and mission success are shown in Figure 12.

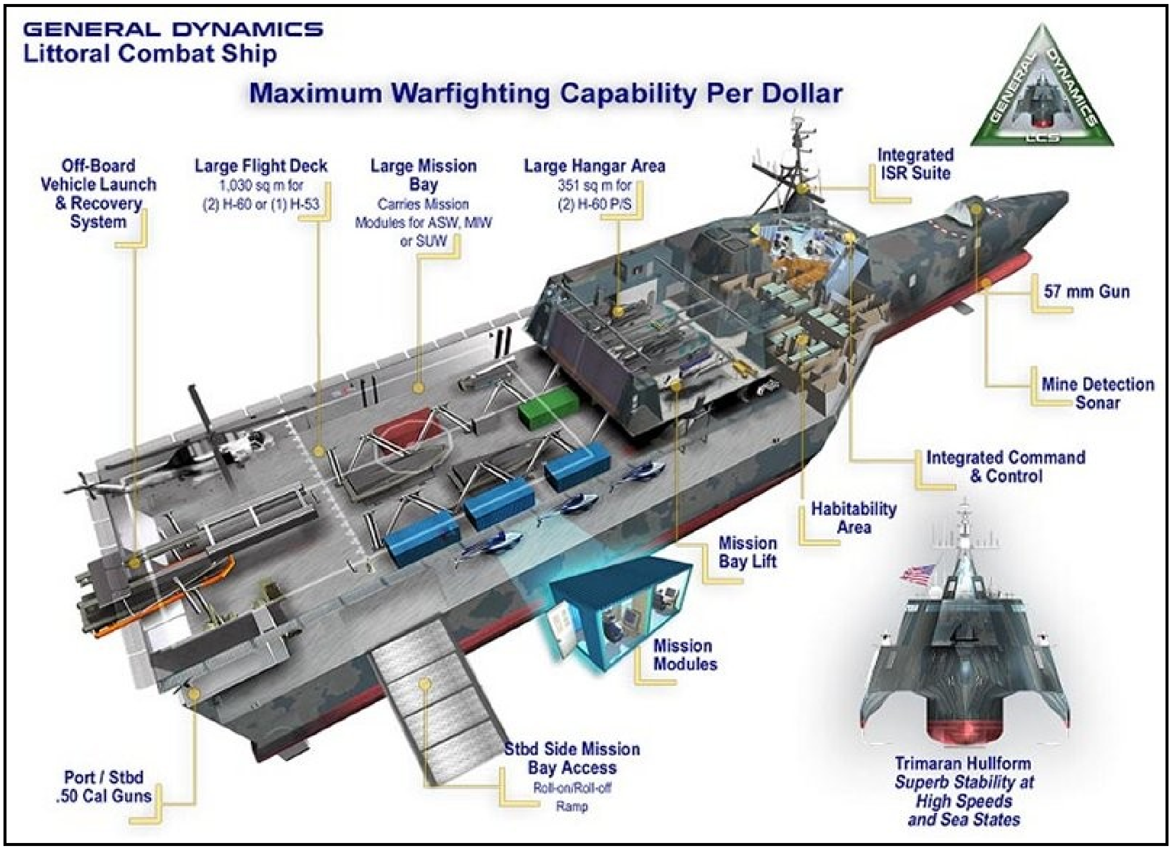

Figure 12. Trimaran Hull (From: General Dynamics LCS Team, 2009)

E. LCS MISSION PACKAGES

A critical feature of the LCS is its ability to change out mission packages within 24 hours. Within this timeframe, an MP will be tested and ready for use. The MP provides each LCS its primary war-fighting capability for specific littoral missions. An MP might include a combination of MMs, manned or unmanned vehicles, sensors, weapons, support equipment, and crew detachments. Each seaframe has module stations and/or module zones that allow for the integration of MMs. This process is optimized by the ship's open-system architecture. Mission requirements will determine which MP will be integrated onboard the LCS.

Figure 13 illustrates the mission package and its components: mission systems, mission modules, and mission crew, which equate to the LCS's focused mission capability.

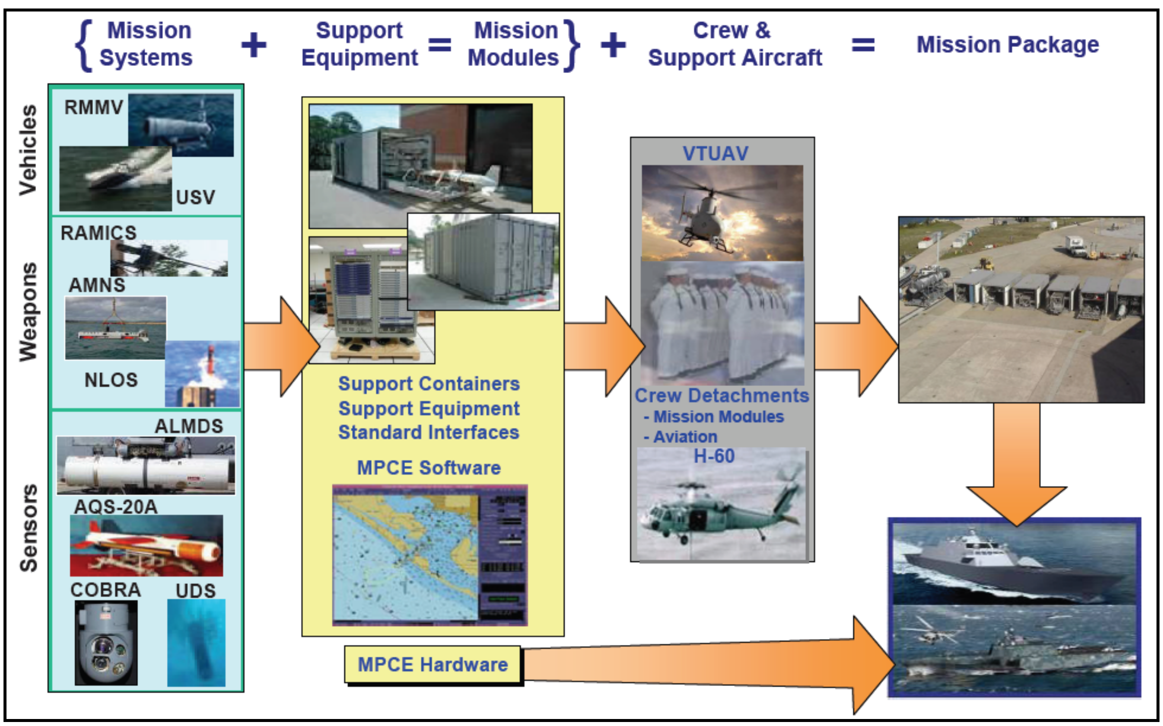

Figure 13. Mission Package Defined (From: PEO LMW, 2009)

1. Mine Countermeasure (MCM)

The MCM mission package allows the LCS to neutralize all mines in a given littoral area by detecting, classifying, and identifying surface, moored, and bottom mines. When tasked, the LCS will utilize its MCM capability to clear transit lanes and sea lines of communication (SLOC), as well as establish and maintain mine clearance areas (Parsell, 2010a). When conducting MCM warfare missions, the LCS will be able to conduct the following tasks:

- Perform mine reconnaissance
- Employ and support MH-60S during MCM operations
- Embark an EOD detachment during MCM operations
- Coordinate and support joint assets during MCM operations
- Perform bottom mapping (Pike, 2008)

2. Anti-Submarine (ASW)

The ASW mission package allows the LCS to detect all submarine threats in a given littoral area and destroy those that pose an immediate threat (Parsell, 2010b). Specific tasks that the LCS must perform while operating with the ASW mission package are guard forces in transit; defend the joint operating area; and create ASW barriers. The LCS will also conduct multi-sensor ASW detection, localization, tracking, and engagement of submarines while navigating in the littoral regions. Other capabilities that the LCS will perform while equipped with the ASW mission package are as follows:

- Conduct offensive ASW operations
- Conduct defensive ASW operations
- Maintain a surface picture while executing ASW operations
- Support MH-60R helicopters while conducting ASW operations
- Perform integrated underwater surveillance (Pike, 2010)

3. Surface Warfare (SUW)

The SUW mission package will enable the LCS to assess a mission kill on all small surface craft threats before they reach weapons release in a given littoral area

(Parsell, 2010a). While equipped with an SUW mission package, the LCS will escort other naval vessels through choke points around the world and protect the Joint Operating Area when required. Additionally, the LCS SUW mission package will engage surface threats by performing the following functions:

- Conduct integrated surface surveillance using its ship's sensors
- Identify both enemy and friendly surface combatants and vessels
- Support MH-60S helicopters while engaged in SUW operations
- Utilize its SUW Battle Damage Assessment
- Engage surface threats independently or jointly (Pike, 2008)

4. LCS Inherent Capabilities

In addition to performing its focused mission capabilities, the LCS will perform other critical functions as a result of its speed, agility, and shallow draft. These critical functions will be in support of the following areas: Personnel transport, Surveillance and Reconnaissance, Naval Special Warfare, Maritime Intercept Operations, Homeland Security, and Antiterrorism and Force Protection (AT/FP) (Pike, 2008).

a. Personnel Transport

The LCS's speed, superior maneuverability, and low draft allow the LCS to transport personnel and materiel when required. For example, this limited strategic lift enables the LCS to transport military personnel, supplies, and required equipment directly from the littoral operating area to shore. The LCS can accomplish this transport function because of the following support capabilities:

- Cargo stowage facilities
- Berthing facilities
- Refuel airborne and waterborne vehicles required for specific missions (Pike, 2008)

b. *Intelligence, Surveillance, and Reconnaissance (ISR)*

In the intelligence, surveillance, and reconnaissance (ISR) core function, the LCS will collect and process ISR data by utilizing Information Operations, Electronic Warfare, Military Deception, Operation Security, and Psychological Operations. As a result of using these ISR elements, LCS intelligence personnel can perform the following tasks:

- Conduct ISR planning and coordination
- Conduct surveillance and reconnaissance operations
- Collect, process, and relay strategic, operational, and tactical ISR information (Pike, 2008).

c. *Naval Special Warfare*

In addition to supporting the movement of Special Operating Forces (SOF), the LCS will be equipped to support the following SOF and Naval Special Warfare capabilities:

- Joint Special Operating Forces hostage rescue aircraft support
- Tactical Sensitive Compartmented Information Facility
- Combat Search and Rescue operations
- Medium-Range Insertion Craft
- Compressed air for SEAL Delivery Vehicle (Pike, 2008)

d. *Maritime Intercept Operations*

The fourth inherent capability that the LCS will perform is maritime intercept operations (MIO). The MIO capability enables the LCS to protect the littoral regions by intercepting enemy surface combatants with the use of warning and/or disabling shots. The LCS will accomplish the MIO function by supporting the following tasks:

- Stowage for MIO equipment
- Holding center for detainees
- Helicopter operations support during MIO (Pike, 2008)

e. Homeland Defense

The LCS will support national and coalition policy by conducting joint missions with the U.S. Coast Guard in support of both U.S. national security and homeland defense objectives. In support of homeland defense, the LCS will perform the following functions:

- Stowage facilities for boarding teams
- Maritime Law Enforcement Operations
- Counter-narcotics Operations
- Emergency, humanitarian, and disaster assistance

f. Antiterrorism / Force Protection

In support of antiterrorism/force protection, the LCS will provide security to both the U.S. and their allies using passive and/or active weapon measures to delay, deter, and protect against adversarial threats. The LCS will perform the following functions:

- Port security
- Restricted maneuvering escort security
- Stowage and berthing facilities in support of Force Protection personnel (Pike, 2008)

F. LCS NON-MISSION-MODULE WARFARE CAPABILITIES

In the absence of a mission module, the LCS still has specific warfare capabilities that allow the ship to operate in the littoral zones. With its basic seaframe, the LCS has operational sensors, weapons, navigational equipment, the capability to receive and relay data to the Common Tactical Picture (CTP), and perform limited operational tasking. All three littoral MP arrangements allow the ship to navigate safely.

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IV. MISSION PACKAGE SUPPORT FACILITY (MPSF)

A. INTRODUCTION

On October 16, 2009, the Program Executive Officer—Littoral and Mine Warfare (PEO LMW), Littoral Combat Ship Class Squadron (LCS CLASSRON), and Naval Surface Warfare Center, Port Hueneme Division (NSWC PHD) established the U.S. Navy's first ever Littoral Combat Ship (LCS) Mission Package Support Facility (MPSF) at Naval Base Ventura County (NBVC) (Bulick, 2009). The decision to establish the MPSF organization within NBVC was based upon a NAVFAC feasibility study, which determined that transforming existing NBVC infrastructure to support the requirements of the LCS Mission Package Program not only was the most cost-effective solution, but also allowed the Navy to meet important milestones in its schedule to stand up the facility (Bulick, 2010). Additionally, the study also concluded that NBVC's current support network would enable the MPSF organization to utilize its deep-water port facility, allow access to Naval Air Base Point Mugu's air and rail network, and utilize NBVC's engineering and technical resources (Navy NewsStand, 2010).

B. MPSF BACKGROUND

The 42,400-square-foot MPSF is a Navy organization operated primarily with civilian government employees and contractors. The LCS CLASSRON in San Diego, CA will be operationally responsible for the MPSF, while NSWC PHD will provide administrative supervision of the facility (Bulick, 2009). Contractors hired by the LCS Mission Modules Program Office will conduct Mission Module maintenance and integration within the facility (PMS 420, 2009). The MPSF will play an essential role in the support and mission readiness of the Navy's LCS program.

The MPSF was established to provide direct support to the LCS fleet as the logistics hub for Life Cycle support and management of the MPs. The current plan is to support 64 mission packages that a fleet of 55 LCS ships will use in the future. This logistics concept includes the implementation of preventive and corrective maintenance

for the individual mission systems and support equipment that represent a mission module. The MPSF will ensure that MM are operationally tested and ready for use before integrating the MP on a seaframe. The MPSF will manage the embarkation and debarkation of MPs as directed by the LCS CLASSRON (MOPM, 2010).

1. Mission Package Support Facility Infrastructure

The MPSF will act as the LCS's primary logistics and technical support activity in the management and maintenance of the MPs. The 42,400-square-foot facility infrastructure includes the following resources, which enable the MPSF to effectively support the LCS fleet via distance support and/or locally, 365 days a year, without interrupted service: 33,000-square-foot high bay; 87,000-square-foot fenced lay-down area; high bay bridge crane; secure mission package computing environment; access to secret internet protocol router network (SIPRNET); secure vault; visitor work center; and sensor maintenance shop (Parsell, 2010a).

C. PRIMARY MISSION OF MPSF

The primary mission of the MPSF is to provide the following services in support of the LCS MMs: Operational, Intermediate, and Depot-level maintenance; distance support of deployed MMs; configuration of certified deployable assets; troubleshooting and repair of systems; ready-for-use testing; inventory management of MMs; validation of ready-for-issue status of MPs; confirmation that authorized spare parts are onboard the LCSs; replenishment of repair and consumable parts; expedition of parts request as required; coordination of transportation of MMs; and pier/crane Services (Parsell, 2010a).

In order for MPSF to effectively support the management and operational availability of each MP, related containers, and support equipment, MPSF will have to rely on the following logistic functions to successfully sustain LCS mission readiness: Mission Module Configuration Management, Mission Module Maintenance, and Inventory Management and Tracking System (MOPM, 2010).

1. Mission Module Configuration Management

MPSF requires detailed procedures and processes in the execution of its Configuration Management (CM) function. The MPSF has made configuration tracking a top priority. As MM parts are received, each item will have its IUID scanned using its UII or IUID bar code. If an IUID mark does not exist, MPSF will generate an IUID label for the item and place it in accordance with the MPSF IUID plan (MOPM, 2010).

2. Mission Module Maintenance

The primary purpose of the MM maintenance process is to sustain LCS mission readiness through scheduled and corrective maintenance of MM systems. This process helps MPSF personnel to identify, complete, and report all related equipment maintenance actions on MM sets. Additionally, this section outlines the roles and responsibilities of the organizations involved with identifying, scheduling, and performing scheduled or corrective maintenance on an MM set installed onboard a seaframe (MOPM, 2010).

3. Inventory Management and Tracking System

PMS 420L retains overall responsibility for MM inventory management and replenishment of appropriate MMs in coordination with the MPSF. Each MM will be inventoried when it is received by MPSF, and designated items within each MM will be inventoried prior to storage. The MPSF logistics team will take action to replenish MMs, subject to PMS 420L guidance. When required, the MPSF logistics team will stock only parts or equipment that are necessary to support demand generated by the MM maintenance actions. The number of MM line items and quantities may increase over time as the MM population increases and as functions performed by the MPSF grow. Most MM replacement consumables parts will be shipped from interim support, NAVICP, DLA, or OEM. Once the requirements arrive at MPSF, the logistics team will receive the item(s) and coordinate with the ISEA or OEM to install the part(s) on the designated MM, or it will ship it to the LCS for installation by the deployed MM detachment or fly-away team, comprised of ISEA or OEM personnel (MOPM, 2010).

a. MPSF-IUID Implementation Plan

The PMS 420 LCS MP Integrated Logistics Support (ILS) managers will provide guidance and policy for implementing IUID for the LCS MM. The MPSF implementation plan details the processes involved for implementing IUID and determining the optimal opportunity to mark MM inventory, support equipment, and containers. When MM and mission systems parts are delivered to MPSF, members of the MPSF logistics team will identify the parts and determine which items will require IUID markings (PMS 420, 2009).

D. MISSION PACKAGE EQUIPMENT

The MPSF will be accountable for the mission readiness of all three LCS MPs. Each MP will be equipped with vehicles, sensors, and weapons. The MPSF will manage and track all MM assets by assigning a serial number to each item and/or marking items with an IUID label. The IUID label will be used when the MPSF team or PMS 420 requires the item to have an IUID mark.

1. Mine Countermeasure (MCM) Mission Package

The MCM MP includes the following equipment in support of its littoral mission:

- Vehicles: MH-60S Helicopter, Vertical Takeoff Air Vehicle (VTAV), Unmanned Surface Vehicle, and Remote Multi-Mission Vehicle
- Sensors: Airborne Laser Mine Detection System, Coastal Battlefield Reconnaissance and Analysis, and AN/AQS-20A Mine Hunting Sonar
- Weapons: Airborne Mine Neutralization System and Rapid Airborne Mine Clearance System (Parsell, 2010a)

Figure 14 illustrates the MCM MP and its related equipment.

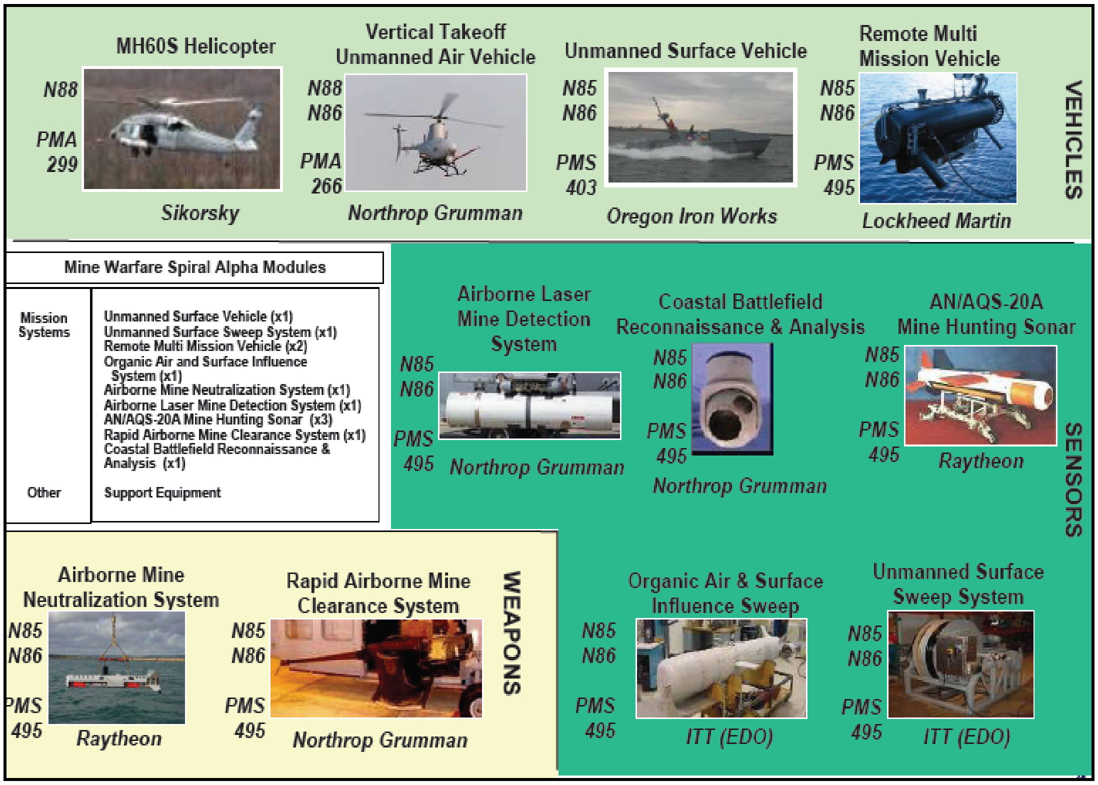

Figure 14. Mine Countermeasure (MCM) Mission Package (From: Parsell, 2010b)

2. Anti-Submarine Warfare (ASW) Mission Package

The ASW MP includes the following equipment in support of its littoral mission:

- Vehicles: MH-60R Helicopter, Vertical Takeoff Air Vehicle (VTAV), Unmanned Surface Vehicle, and Remote Multi-Mission Vehicle
- Sensors: Dipping Sonar, Sonobuoys, USV Towed Array System, Remote Towed Active Source, Multi-Static Off-Board Source, Multi-Function Towed Array and Handling equipment
- Weapons: MK 54 Torpedo (Parsell, 2010b)

Figure 15 illustrates the ASW MP and its related equipment.

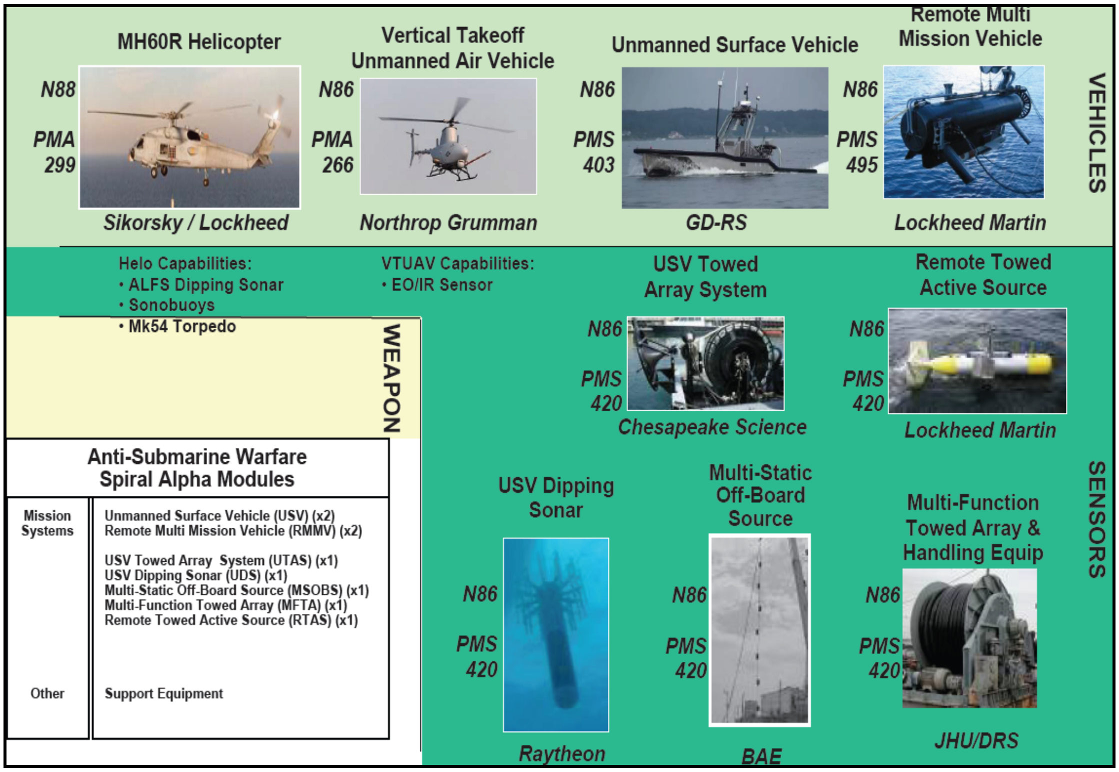

Figure 15. Anti-Submarine Warfare (ASW) Mission Package (From: Parsell, 2010b)

3. Surface Warfare (SUW) Mission Package

The SUW MP includes the following equipment in support of its littoral mission:

- Vehicles: MH-60R Helicopter and Vertical Takeoff Unmanned Air Vehicle (VTUAV)
- Sensors: Electro-Optical (EO)/Infrared (IR) Sensors
- Weapons: Non Line of Sight-Launching System (NLOS-LS) and 30mm Gun (Parsell, 2010b)

Figure 16 illustrates the SUW MP and its related equipment.

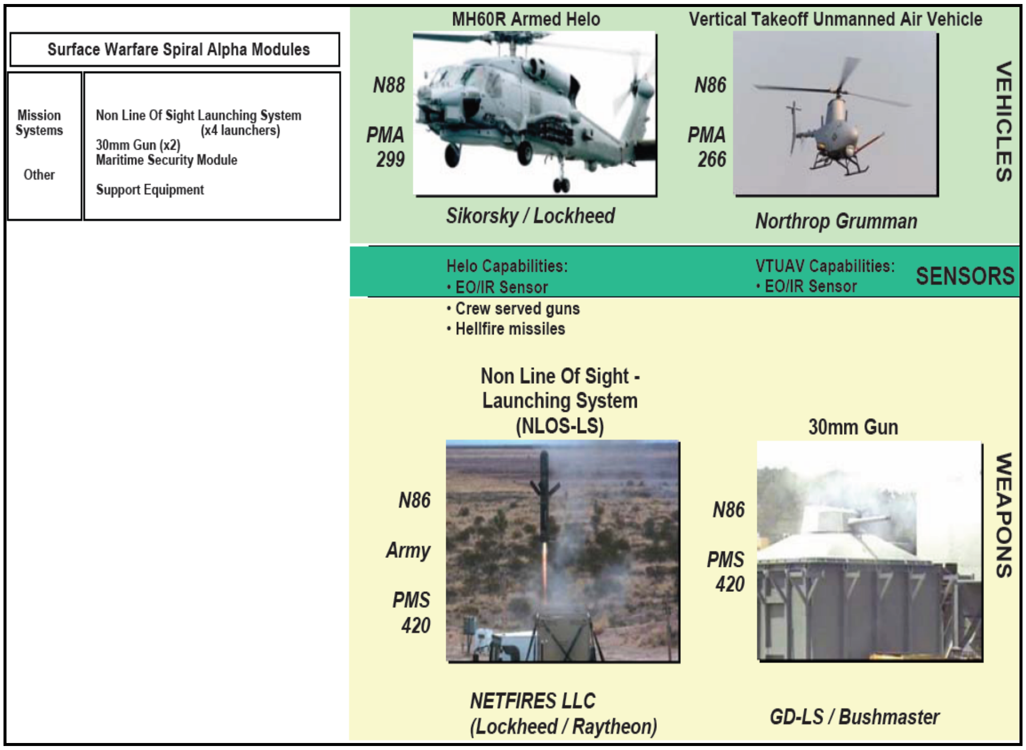

Figure 16. Surface Warfare (SUW) Mission Package (From: Parsell, 2010b)

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V. ANALYSIS

A. INTRODUCTION

This chapter begins by introducing four instances in which items requiring an IUID mark do not have the required mark. Later in the chapter, an analysis of possible remedies for these four instances will be covered. The intention is to provide PMS 420 with viable, cost-effective alternatives to be used in accordance with the IUID policy, while, at the same time, maintaining asset visibility through IUID use. The four instances are as follows:

1. Items have a new need for marking (e.g., parts with higher-than-usual mean time between failures (MTBF)).
2. A direct requisition from an OEM does not provide an IUID mark for its components that go directly to a ship or prepositioned site.
3. The mark becomes damaged or is missing from the component.
4. Legacy items have not been marked.

In attempting to solve these potential problems in order to adhere to the IUID policy, the research team came up with the following possible solutions:

1. Have a parts-marking cart at each location (ship, prepositioned site, MPSF).
2. Use IUID temporary marks until the item is routed through the MPSF for permanent marking.
3. Wait until equipment is brought to the MPSF during maintenance availabilities.
4. Use electronic transmission of IUID data for on-site marking.
5. Make site visits to LCS concentration areas (Mayport, Florida and San Diego, California).

A process-analysis approach will be used to analyze the data. In order to provide the MPSF with a return on investment with IUID, flow-time reduction through implementation of IUID will provide more details for deciding which of the alternatives to pursue. Also, Logical Decisions® for Windows will be utilized to determine the best solution to pursue.

B. DESCRIPTION OF INSTANCES OF A MISSING IUID TAG ON A COMPONENT

Even with a plan to ensure compliance with the DoD's IUID policy, the research team, with the assistance of the MPSF, has discovered a few instances in which a part requiring an IUID mark does not display a mark. In order to understand the possible scenarios involving missing or damaged IUID marks, it is important to note the Littoral Combat Ship (LCS) Mission Module (MMs) Unique Identification (UID) Plan, constructed by members of the LCS Mission Modules Program Office (PMS 420). In the plan, PMS 420 takes into account DoD's policy memorandum regarding the mandatory requirement to implement IUID, in addition to some of their own inputs for items that require an IUID mark. According to the plan, items deemed IUID-worthy exhibit the following characteristics:

- The item's government unit acquisition cost is $5,000 or more.
- The item is DoD serially managed.
- The item is mission-essential.
- The item is inventory-controlled.
- The item is repairable (maintenance-worthy).
- The item has a UID equivalent (e.g., a vehicle identification number [VIN]).
- The item may need to be located at some future time.
- The program manager designates the item IUID-worthy
- Regardless of value, any DoD serially managed subassembly, component, or part embedded within a delivered end item or spare, and the parent item that contains the embedded subassembly, component, or part. (PMS 420, 2009)

The research team determined other scenarios that were not specifically mentioned in the UID implementation plan for the LCS MMs. An explanation of each scenario follows.

1. Need for Marking (Parts with Lower-Than-Usual MTBFs)

The emergent need to mark an item was not discussed in the MPSF UID implementation plan. This specific need arises when equipment that did not meet the UID implementation plan's requirements has now become a candidate for IUID marking. One such instance is a circuit card with a discovered MTBF that is lower than previously estimated. Although there is an unforeseen requirement to mark the item, no process of marking can be accomplished while the ship is deployed.

2. Direct Requisition from Ship Prepositioning Site

The direct requisition from the ship brings to mind the possibility that a part belonging to any of the MMs is not marked with an IUID mark coming from the original equipment manufacturer (OEM). In the process of a ship receiving a part while it is deployed, the OEM forgoes the MPSF in order to meet the demand of the LCS.

One may think that this would not necessarily be an instance of an item missing an IUID mark—partly due to a Defense Federal Acquisition Regulation Supplement (DFARS) in Part 252 for Solicitation Provisions and Contract Clauses that gave specific instructions to contractors to provide IUID marks on items specified in the policy (DFARS, 1998). With the attached clause on items pertaining to LCS Mission Modules, the likelihood of an item requiring an IUID mark *not* having the mark decreases. Despite this decrease, the DFARS clause in contracts with suppliers of equipment for the LCS MM does not take into account materiel that is deemed an IUID candidate under the LCS MM implementation plan of PMS 420. With a more descriptive list of items that require an IUID mark in the PMS 420 UID Implementation Plan, there is a greater chance that items requiring an IUID mark will not have it.

Having a site that contains some functionality of the MPSF in other ports, entails having the necessary capability to procure items that an LCS may need while deployed. As a result, a problem similar to the one cited above arises in a prepositioned site. Items

ordered by the ship would go to these sites prior to being placed on a ship. In some cases, a direct requisition from the OEM would provide another instance in which an item requiring an IUID mark did not have the necessary mark.

3. Damaged or Missing IUID

In the middle of any deployment, equipment can become damaged or be used for whatever mission an LCS is assigned. When the deployed LCS uses equipment, IUID marks can easily be damaged. As a result, IUID marks may come up missing or damaged during the utilization of any equipment in the MM. The lack of the IUID is a loss, not only of the ability to uniquely identify items in the MM inventory, but also of the capability to keep track of those items and to adhere to the 2003 policy memorandum.

4. Legacy Items

The term “legacy” refers to items that are not newly procured items from an OEM. These items are installed on the seaframe and do not belong to the MMs, but they may interface with the MM components. As a result, these items fall under the IUID implementation plan for the MPSF.

With each of the four situations described above, the need to maintain proper accountability of the MM inventory remains paramount. Degradation to the current process involving IUID implementation only increases the amount of time it takes to conduct an inventory and provide proper asset visibility. The next section will provide options for PMS 420 to implement and ensure that there is no loss of asset visibility from any of the above instances. This will maintain the most relevant return on investment on IUID implementation: man-hours saved from reduced inventory-processing time.

C. POSSIBLE COURSES OF ACTION

The research team has identified possible solutions to the problems facing the MPSF with regard to IUID implementation. This section presents specific solutions, as well as cost estimates for each. Before looking at each course of action, it is vital to

understand the differences in the overall inventory process when IUID is implemented versus when it is not. This will help to show the benefit of IUID in minimizing lifecycle management costs, reducing the time to conduct an inventory at MPSF.

1. The Inventory Process

Although the implementation of IUID has already begun, inventory managers and members of the research team have a general idea of how to conduct an inventory without IUID. With this understanding of inventory management, and using a process similar to that in Obellos et al., (2007), as well as confirmation of the inventory process with the MPSF, Figure 17, which shows the inventory process without the use of IUID, was generated. Figure 17 depicts the following process:

The person conducting the inventory:

1) prints the inventory worksheets.
2) counts the stock items once the inventory worksheets are printed.
3) records the number of items counted on the worksheet.
4) with the information needed gathered from the initial inventory, inputs inventory data in the resident inventory management system.
5) prints a discrepancy report.
6) determines if a recount is necessary.
    a) If there are no discrepancies, the inventory is complete and a master inventory report is printed.
    b) If there are discrepancies, the discrepancy report is used to conduct a recount.
7) records the recount of the discrepancies on the discrepancy worksheet.
8) inputs the recount data into the inventory management system.
9) prints out a final discrepancy report.
10) prints out the master inventory report.

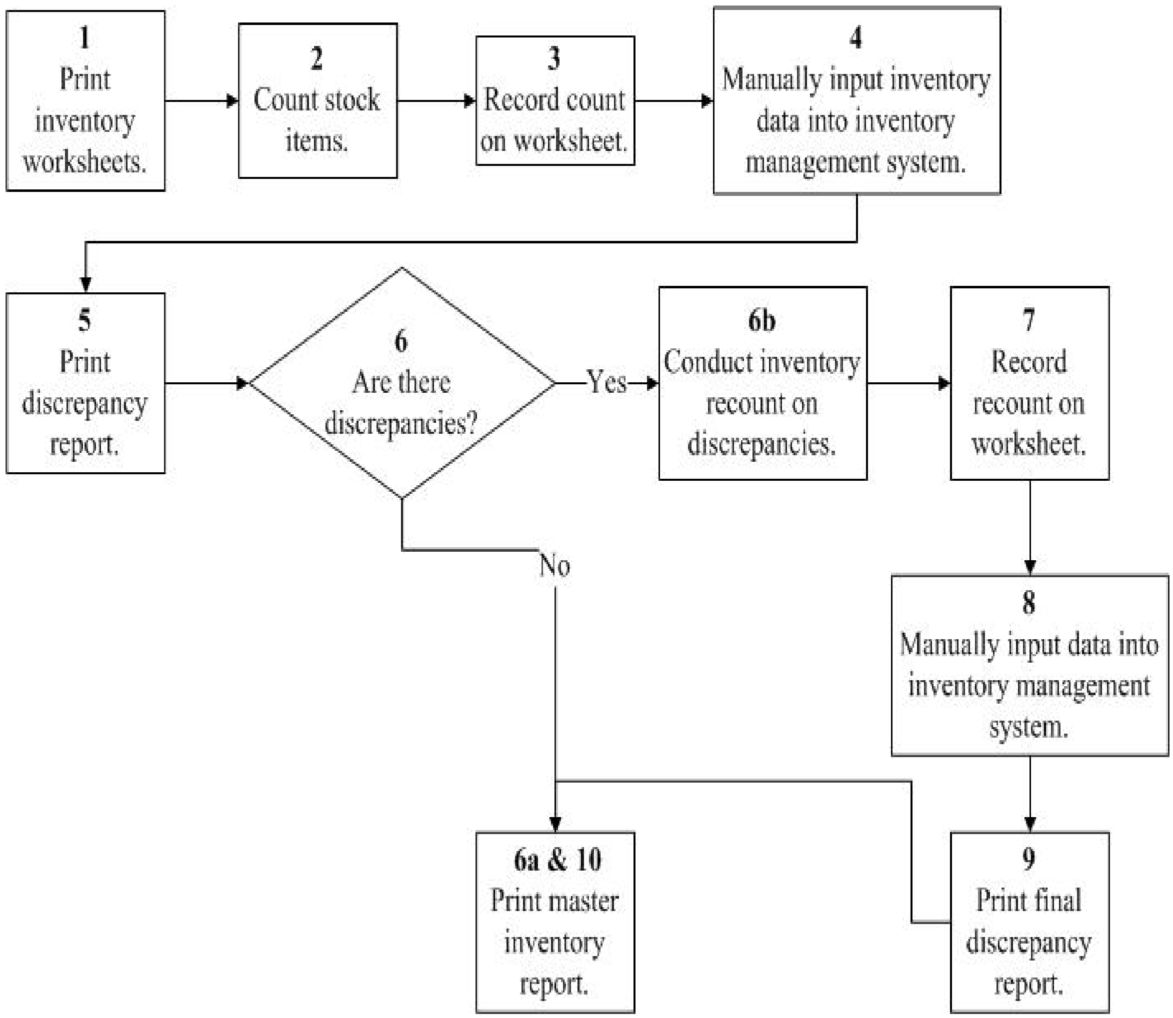

Figure 17. Process Flowchart for the MPSF Inventory Process Without IUID

It is assumed that the person conducting the inventory without IUID implemented does manual inputs in addition to conducting the physical inventory of MM components.

The following table shows the times associated with each of the operations in the inventory process without using IUID. Total times are shown for the processes with and without discrepancies to report. An inventory of 25 items was used to determine the times for each of the inventory processes.

Inventory Process without IUID	Time to conduct each operation (mins) (NO DISCREPANCIES)	Time to conduct each operation (mins) (WITH DISCREPANCIES)
1) Print inventory worksheets	5	5
2) Count stock items	30	30
3) Record count on worksheet	10	10
4) Manually input inventory data into inventory management system	15	15
5) Print discrepancy report	5	5
6) Conduct Inventory recount on discrepancies	N/A	15
7) Record recount on worksheet	N/A	5
8) Manually input recount data into inventory management system	N/A	5
9) Print final discrepancy report	N/A	5
10) Print master inventory report	15	15
Total Time	**80**	**110**

Table 1. Inventory Times for the MPSF without IUID (From: Obellos et al., 2007)

Times shown in Table 1 are approximate average times, depending on the type of inventory being conducted (wall-to-wall, location, random). Wall-to-wall inventories are a complete inventory of the MPSF. Location and random inventories are types of spot-check inventories that pick a portion of the MPSF to conduct an inventory. Location spot-check inventories involve checking inventory in a designated location of the warehouse, whereas a random spot-check inventory utilizes a random selection of inventory that is spread throughout the warehouse. Due to its flow-time-reduction appeal, MPSF members most often conduct a location spot-check inventory.

Since implementation of IUID has begun at the MPSF, the main reduction in life-cycle management costs comes from the reduction in the time it takes to conduct an inventory. Figure 18 is a process flowchart that shows the following:

The person conducting the inventory:

1) prints the inventory worksheets.
2) utilizes a handheld device (scanner) once the inventory worksheets are printed.
    a) transmits the inventory count wirelessly to the inventory-management system.
    b) sends inventory data to the inventory-management system wirelessly.
3) prints a discrepancy report.
4) determines if a recount is necessary.
    a) If there are no discrepancies, the inventory is complete and a master inventory report is printed.
    b) If there are discrepancies, the discrepancy report is used to conduct a recount.
        1. Discrepancy inventory count is transmitted wirelessly to the inventory- management system.
        2. Other discrepancy inventory data are sent to the inventory-management system wirelessly.
5) prints out a final discrepancy report.
6) prints out the master inventory report. (Obellos et al., 2007)

With the addition of IUID, information flow is added to the process. Solid lines relate to the flow of the printed inventory worksheets, and dotted lines refer to the flow of information.

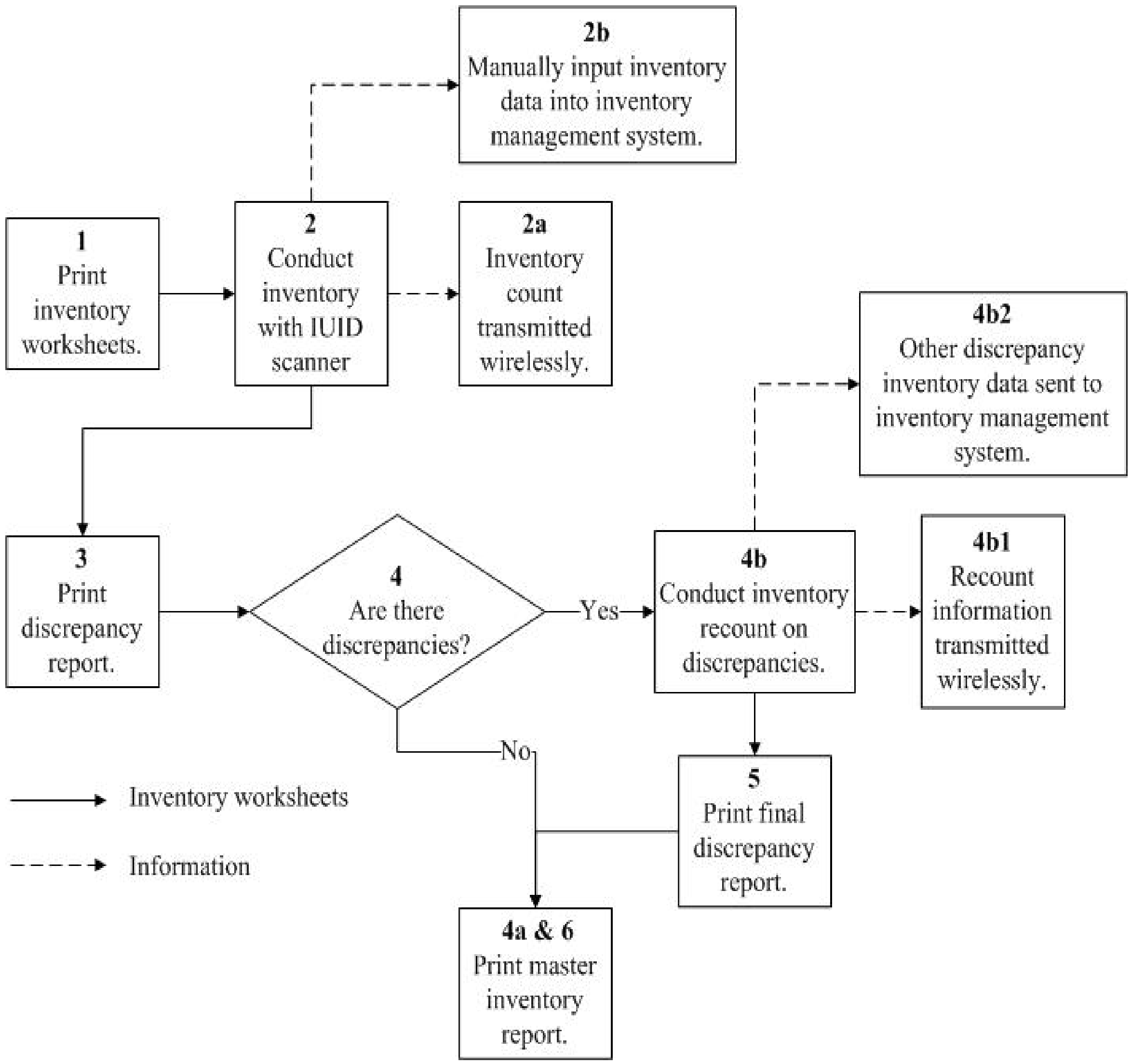

Figure 18. Process Flowchart for Inventory Process at MPSF with IUID

The most notable difference between Figures 17 and 18 revolves around the flow of information in an IUID environment vice an environment lacking IUID. Information flow from the scanner to the database is instantaneous. Without the burden of having to read each serial number or having to manually enter it into the inventory database, IUID provides a means to shorter inventory times.

Times associated with Figure 18 are observed in Table 2. Twenty-five items were used to demonstrate this process, as well. Of note is that the inventory times have dramatically decreased with the implementation of IUID.

Inventory Process with IUID	**Time to conduct each operation (mins) (NO DISCREPANCIES)**	**Time to conduct each operation (mins) (WITH DISCREPANCIES)**
1) Print inventory worksheets	5	5
2) Conduct inventory with handheld device with data transmitted wirelessly to inventory management system	15	15
3) Print discrepancy report	5	5
4) Conduct inventory recount and data transmitted wirelessly to inventory management system	N/A	10
5) Print final discrepancy report	N/A	5
6) Print master inventory report	15	15
Total Time	**40**	**55**

Table 2. Table for Inventory Times for the MPSF With IUID (From: Obellos et al., 2007)

With less time needed to conduct an inventory, costs are avoided—the main one being the cost of labor hours. This opens up time for the person or persons conducting an inventory to focus on other matters, thus increasing efficiency at the MPSF.

The reduction in inventory time plays a key role in the choice to possibly involve ship's force or mission-package personnel in implementing IUID on the LCS platform. One of the objectives behind LCS was to provide a ship that carries minimal personnel, and keeping the inventory time for MMs down supports this objective. Although the reduction in inventory time is a clear benefit of IUID, to achieve the program's full potential, its implementers must ensure that the appropriate items are marked.

In generating an IUID mark for an item, the considerations discussed in the MPSF UID implementation plan are of crucial importance. The process of marking an item is as follows:

1) After receipt of parts, if there is no IUID, does the item require an IUID?

   a) If the part does not require an IUID, conduct normal inventory procedures.

   b) If the part does require an IUID, generate construct data for the mark.

2) Generate an appropriate IUID mark. To determine an appropriate mark, the MPSF conducts an engineering analysis. This analysis is in accordance with the appendix in the LCS MM UID Implementation Plan and takes into account the type of mark best suited for a part.

3) Verify that IUID construct data are correct.

4) Place the IUID mark on the part.

5) Link the line item with the IUID mark.

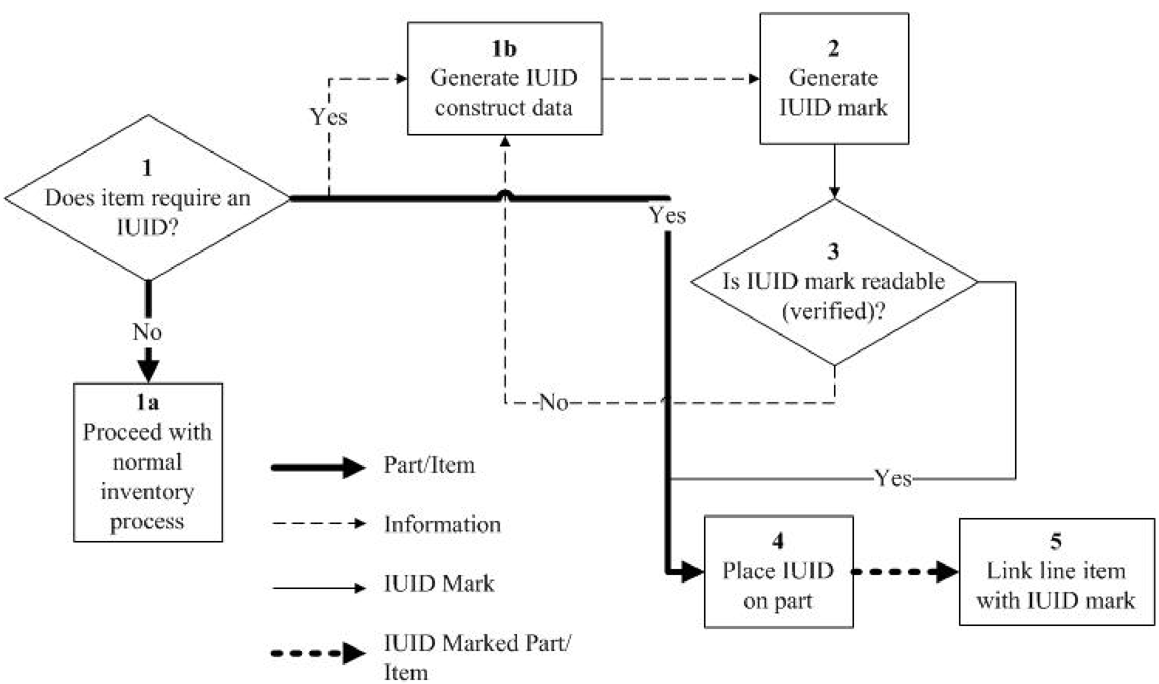

Figure 19. Process Flowchart for IUID Parts Marking

The process flow chart in Figure 19 shows the general IUID marking process for any parts receipt site. Operations in the initial marking process take time to complete. In order to appreciate the reduced time to conduct inventories, the parts-marking process is required to ensure that data for each part are uniquely identified.

Depicted in Table 3 are the times associated with the parts-marking process.

IUID process	**Time to conduct each operation (mins)**
1) Identify assets / parts for IUID marking	15
1b) Generate construct data for each mark	15
2) Generate IUID marks	15
3) Verify IUID construct data is correct	5
4) Place IUID mark on part	10
5) Link line item with IUID mark	10
Total Time	**70**

Table 3. List of Times to Conduct Parts Marking for 25 Items

Table 4 shows the times associated with creating an IUID mark for one item.

IUID process	**Time to conduct each operation (min)**
1) Identify assets / parts for IUID marking	0.6
2) Generate construct data for mark	0.6
1b) Generate IUID mark	5.4
4) Verify IUID construct data is correct	0.2
3) Place IUID mark on part	0.4
5) Link construct data with IUID mark	0.4
Total Time	**7.6**

Table 4. List of Times to Conduct Parts Marking for One Item

As Table 4 shows, it takes approximately five minutes to generate an IUID mark. Once the setup is complete, it takes about 24 seconds to print out each mark.

With an initial parts-marking process, the ability to inventory more quickly is greatly enhanced. The analysis in this research determined that the MPSF and PMS 420 would value the overall reduction in inventory time as the return on investment. In considering each of the options for ensuring compliance with the IUID policy, the research team will modify this initial parts-marking process as needed to help depict how IUID assurance can be guaranteed.

2. Possible Solutions

a. Having A Part-Marking Cart at Each Part Receipt Location (Ship, Prepositioned Site, MPSF)

Parts-marking carts give the capabilities needed at part receipt sites in the supply chain of MM items. Having the marking cart at these various locations allows for immediate visibility of a component through IUID marking, thereby providing immediate compliance. However, some issues with this course of action must be considered prior to implementation. One of these issues is cost.

Prices vary according to the equipment involved and the capabilities required of the IUID system. For the pricing analysis of the equipment needed to implement this and other possible solutions, an average retail price for each item was taken. In addition, the items used in the analysis were as close as possible to those in the IUID system being used by the MPSF. Requirements for an IUID system include a laser engraver, a printer, label-making software, a verifier, and scanners with built-in computers for spreadsheet annotation of inventory. Table 5 presents the prices of these components.

Items in IUID System	**Amount Needed**	**Price/Item ($)**	**Total Retail Costs ($)**
Scanner	2	1,487	2,974
Printer	1	3,050	3,050
Verifier	1	4,495	4,495
Scanner/Computer	2	3,338.5	6,677
Software	1	647	647
Laser Engraver	1	39,885	39,885
Total Price			**57,728**

Table 5. Equipment Investment Needed for Each IUID System

According to a *Defense Industry Daily* online article, “the U.S. Navy is trying to replace 30 FFG-7 Oliver Hazard Perry Class frigates, 14 MCM Avenger Class mine countermeasures vessels, and 12 MHC-51 Osprey Class coastal mine hunters” and will have “about 55 Littoral Combat Ships” (*Defense Industry Daily*, 2010). Without

including the need for prepositioning sites around the globe, supplying 55 LCSs would involve an equipment investment of about $3,175,000[6].

Another facet of this solution is the need to train ship's force personnel or MP personnel to use the IUID system. With personnel from Applied Enterprise Solutions (AES) taking the lead in training MPSF personnel, it is assumed that AES trainers will conduct the necessary training. Training costs would include the costs for travel and per diem of AES training personnel. Not knowing the true cost for providing training, the research team assumed $1,000 for each session, with an average of $1,400[7] (expedia.com & U.S. General Services Administration) for two AES personnel travelling and training for two days. In addition, MPSF personnel would be needed to train a crewmember of the LCS or MP on the MPSF IUID implementation plan for two days, amounting to about $1,500[8] (expedia.com & U.S. General Services Administration). Training costs for each ship would total $214,500, coming to a total investment of $3,389,500.[9]

Another cost of this solution is the impact of training and giving another task to a crew that is utilizing the minimal-manning concept. Overtaxing the crew would create weaknesses in other aspects of the LCS mission, resulting in a decreased level of mission readiness. Having a parts-marking cart in every parts receipt site would require the crew to perform tasks that would take approximately 7.6 minutes from mission-essential tasks, as well as a couple of days to train a crew member or MP member to use the IUID system correctly. In addition, having crewmembers or mission-package members involved in implementing IUID creates more opportunities for the mark data to

[6] The number of MMs is expected to amount to 64. Since the excess MMs would be stored at the MPSF and IUID placed on the MM components, the excess MMs were not taken into account for the calculation.

[7] Assuming two AES personnel are flying from Gulfport, Mississippi to either San Diego, California or Orlando, Florida with the same per diem requirement.

[8] Assuming two MPSF personnel are flying from Los Angeles, California to either San Diego, California or Orlando, Florida with the per diem requirement.

[9] This assumes that training on the equipment will pass on to follow-on crewmembers or MP personnel, and that the minimum requirement is to provide to the proposed 55 LCSs that will be built.

be entered incorrectly. Although the immediate benefit of being in compliance of IUID seems appealing, there remain several issues to take into account before proceeding with this option.

b. Use of IUID Temporary Tags Until the Item is Routed Through the MPSF for Permanent Tagging

Temporary marks contain all the data needed to satisfy IUID construct I, but the IUID label may not be the appropriate label for the item (temporary marks may not be suitable for the environment that the item is subjected to during normal operations).[10] The inventory of items received at a ship or prepositioned site would still be quicker using the temporary mark, and compliance with the policy memoranda would be met. One important benefit is the low cost to implement. Instead of investing in the higher-priced parts-marking equipment, the only investments would involve the purchase of Avery labels—approximately $15,000 per ship for equipment investment[11] (Avery.com). Discussion of this course of action is based on the use of an Avery label and a procedure with items onboard other Navy ships and Maintenance Figure of Merit (MFOM).[12],[13] (MI Technical Solutions, 2010 & R. Leeker, personal communication, March 2, 2010).

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[10] Littoral Combat Ship (LCS) Mission Modules (MMs) Unique Identification (UID) Plan Revision A includes in its appendix an IUID engineering-analysis overview that helps determine what kind of label should be placed on an item in the MPSF.

[11] The cost is without the thermal printer or the laser engraver, but adding the cost of Avery labels at $13.

[12] MFOM is "a software program that consistently and objectively calculates a ship's material readiness and links it directly to cost."

[13] Normal printers with the Bartender IUID software can create a label with an IUID mark. This is done using Maintenance Figure of Merit (MFOM). As part of its functions onboard ships and elsewhere, MFOM automatically assigns an IUID to every item in its database, providing data integrity, regardless of whether or not an IUID label already exists on the item. If an IUID label is already attached to the item, the MFOM information is replaced with the issuing agency's information.

The steps in the temporary-mark process are as follows:

1) After receipt of parts, if there is no IUID, does the item require an IUID?

   a) If the part does not require an IUID, conduct normal inventory procedures.

   b) If the part does require an IUID, generate construct data for the mark.

2) Generate a temporary IUID mark.

3) Verify that the IUID construct data are correct.

4) Place the IUID mark on the part.

5) Link the line item with the IUID mark.

Figure 20 presents the process of administering the temporary mark. The process flow chart is a modification of the initial parts-marking process.

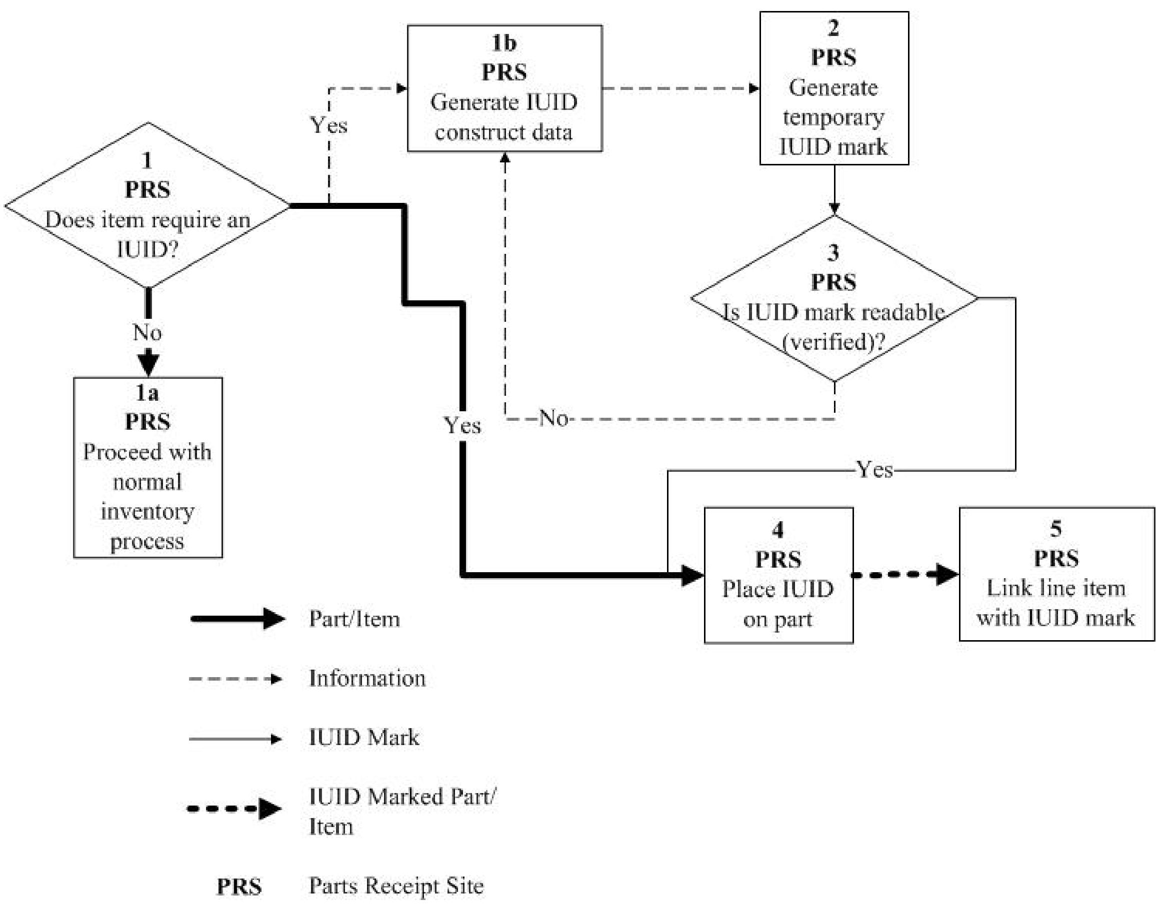

Figure 20. Process Flowchart for Creating Temporary IUID Marks

Associated times for conducting the process in Figure 20 are seen in Table 6.

Temporary IUID Process	Time to conduct each operation (min) (IUID required)
1) ID parts for marking (Does it require IUID?)	0.6
1a) Conduct normal inventory operating procedure	N/A
1b) Generate temporary IUID mark	5.4
2) Generate construct data	0.6
3) Place IUID mark on part	0.4
4) Verify IUID construct data is correct	0.2
5) Link construct data with IUID mark	0.4
Total Time	**7.6**

Table 6. List of Times to Conduct Temporary Parts Marking for One Item

The notable difference between the temporary IUID mark flowchart and the initial IUID parts-marking flow chart is seen in step 1b of each process. If an engineering analysis is not conducted on the item, the temporary IUID mark may not suffice. Items mark this way would not receive the correct IUID label until they were circulated to the MPSF.

Like the previous option, this one calls for utilization of the LCS's crew or MP personnel. Thus, training costs would, once again, be incurred. Costs for training would involve both AES and MPSF personnel. The costs for the entire LCS fleet would total around $1,039,500,[14] accounting for the additional costs of procuring more labels during the lifetime of the MMs. In addition, because the equipment would be exposed to more personnel under this option, there would likely be more mistakes made in entering the data.

[14] This does not take into account the cost of a thermal printer or laser engraver since temporary labels can be made with a word-processing printer.

c. *Wait Until Equipment is Brought to the MPSF During Maintenance Availabilities*

Waiting until equipment is brought to the MPSF during maintenance availabilities is the epitome of opportunistic marking. An LCS returning from deployment, or during a scheduled maintenance availability, enables the MPSF to experience the benefits of a low-cost course of action. There is essentially no cost since the maintenance availability is factored into the lifecycle cost of the LCS and its MMs, and training costs are nil; inventory and marking autonomy remain with the MPSF, reducing the opportunities for mistakes; and there is no detriment to the crew.

The downside to this course of action is that compliance will not be met until much later. Also, if an inventory is conducted prior to a maintenance availability, those items without an IUID would fall under the category of inventory without IUID implemented. This adds costs that would have been avoided had some mechanism to implement IUID been in place. In addition, valuable data on items requiring an IUID mark could not be realized.

d. *Use of Electronic Transmission of IUID Data for On-Site Marking*

Electronic transmission of an IUID label ties in with the temporary marking option presented in option two, but in this option, data-entry autonomy lies with the MPSF. This course of action is as follows:

1) The parts-receipt site receives the item requiring IUID.
2) The parts-receipt site notifies MPSF of parts missing IUID. The communication medium (email, telecommunication) also contains the required information for creating an UII and information needed to make the link between the marked item and the IUID.
3) MPSF generates construct data for the mark.
4) MPSF creates an IUID label for the item in accordance with its engineering analysis appendix in the MPSF UID implementation plan.
5) MPSF verifies that the IUID construct data are correct.

6) a) MPSF sends UII data string via email to the parts-receipt site[15] (S. Phillips, personal communication, May 27, 2010).

   b) MPSF places permanent IUID mark in binder for future use (when the mission module returns to the MPSF, or during a site visit).

7) The parts-receipt site prints the label with IUID software and temporary labels, unless these labels are considered a permanent IUID mark in accordance with the MPSF UID implementation plan's engineering analysis.

8) The parts-receipt site places the IUID on the corresponding item.

9) The parts-receipt site reports to the MPSF that the mark is attached.

10) The MPSF links the line item with the IUID mark.

Figure 21 illustrates the electronic transmission of an IUID from the initial report of the IUID requirement of a part, to when the part is marked with a temporary IUID.

[15] The UII data string contains all the necessary information needed to create a duplicate tag. A UII does not necessarily generate a duplicate tag on its own due to other information that is embedded into the IUID, such as the issuing agency code (IAC).

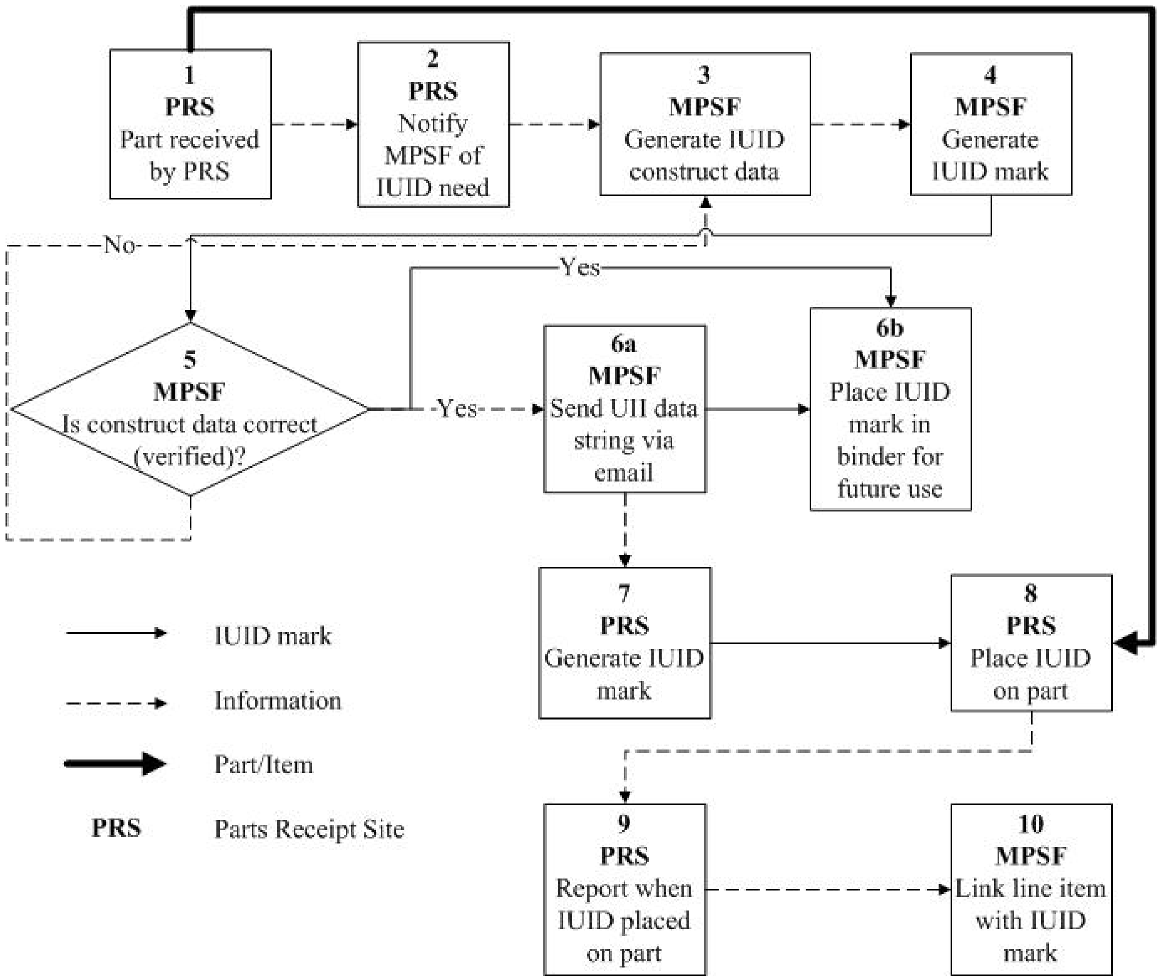

Figure 21. Process Flowchart of Electronic Transmission of IUID

Table 7 reports the times associated with this notional option. Times in the table assume no interruption in the flow of the process due to outside interference, such as ship internet-connectivity problems while at sea.

Electronic Transmission Procedure	Time to conduct each operation (mins)
1) Item received by PRS.	N/A
2) PRS notifies MPSF of IUID requirement	3
3) MPSF generates construct data for the mark.	0.6
4) MPSF creates IUID label	5.4
5) MPSF verifies IUID construct data is correct.	0.2
6a) MPSF sends UII data string via email to PRS.	2.5
6b) MPSF places IUID mark in binder for future use.	0.2
7) PRS prints the label	5.4
8) PRS places IUID mark on part	0.4
9) PRS reports mark is hung to the MPSF.	3
10) MPSF links the construct data with the IUID mark.	0.4
Total Time	**21.1**

Table 7. Electronic Transmission Process Operation Times

This procedure ensures that data entry into the registry is retained at the MPSF, instead of the at the parts-receipt site. In addition, MPSF remains the sole authority for application of a permanent mark, while complying with the IUID policy quickly. In addition, investments in hardware to comply with the policy remain lower than for a full IUID marking suite. Total time spent by personnel conducting the inventory at the parts-receipt site amounts to about 9.1 minutes per part requiring an IUID. However, there still remains an opportunity for mistakes when parts-receipt site personnel communicate the need for an IUID by providing incorrect part information. In addition, with several characters in the UII data string, MPSF personnel could enter the incorrect data string. This would lead to an IUID mark that is not a duplicate of the mark created by the MPSF, degrading the visibility of an item that requires an IUID. Training costs would involve both AES and MPSF personnel. Taking time to train personnel attached to an LCS takes time away from mission-essential requirements with an already minimally manned ship. Total costs are around $1,039,500, similar to the temporary marking option.

e. Site Visits With MPSF Personnel

Site visits eliminate the need to procure marking equipment. In addition, training costs are removed since equipment would not be necessary to carry out this option. This assumes that the MPSF has all the equipment required to create IUID marks and visit all parts-receipt sites. Utilization of the LCS crew or MP personnel is not needed. Data entry is localized to MPSF personnel, reducing the opportunities for error. Although these benefits of site visits are appealing, one major drawback remains, travel costs of MPSF personnel.

Personnel from the MPSF would need to conduct visits whenever an LCS was available. The research team's experience in the fleet suggests that this would most likely occur after the ship returned from deployment. Taking the end of deployment into account for how often an LCS would be available, the cost associated with ensuring that all MMs are within compliance amounts to $333,960.[16] Another drawback to this method is the time it takes to become compliant with the IUID policy. Since visits would most likely be conducted about three times a year to each LCS concentration area, a lengthy amount of time would pass before an item that requires an IUID mark received the mark.

D. LDW ANALYSIS

Using the above descriptions of the possible solutions, the research team set out to determine the option that best optimizes two goals stated by the MPSF, as well as other goals determined by the team through its research on IUID, LCS, and the MPSF. The research team decided that the use of Logical Decisions® for Windows (LDW) would provide an adequate determination of which course of action should be pursued.

According to its website, "LDW draws on tools from an academic discipline called Multi-Attribute Utility Theory to help you make the value judgments needed for a

[16] This figure assumes that a team of two MPSF personnel will travel to the LCS fleet concentration areas of Mayport, Florida and San Diego, California. Also, the figure assumes that the two-person team will make visits three times a year to each LCS concentration area for a duration of five days to ensure that MMs on each LCS are within IUID compliance.

particular decision” (Logical Decisions®, 2010). To conduct its analysis of the alternatives, the research team followed the procedure found in Section 4 of LDW’s Introductory Tutorial. This procedure is described in the following sections.

1. Define Alternatives

Defining the alternatives was conducted in Section C of this chapter. The research team defined the alternatives in the following way:

a) Temporary Marks (Use of IUID Temporary Marks Until the Item is Routed Through the MPSF for Permanent Marking)

b) Wait for Next Availability (Wait Until Equipment is Brought to the MPSF During Maintenance Availabilities)

c) Electronic Transmission (Use of Electronic Transmission of IUID Data for On-Site Marking.

d) Parts-Marking Cart (Having A Parts-Marking Cart at Each Part- Receipt Site (Ship, Prepositioned site, MPSF))

e) Site Visits (Site Visits with MPSF Personnel)

2. Define Goals

Defining goals allows the research team to determine the issues most important in deciding which course of action to take (Logical Decisions®, 2010). For the analysis, the overall goal is to pick the best course of action, taking into account the boundaries that the research team has identified as the sub-goals. The following sub-goals were derived from the initial problem of the MPSF and from the past experience of the research team as inventory managers:

a) Minimize Costs—These are costs for equipment and training.

b) Minimize Crew Burden—According to Douangaphaivong, due to LCS’s design as a minimally manned ship, “to assist in this goal, the crews will be supported by ‘just-in time training, distance learning, distant support and maintenance.’ LCS will not have ‘the wide variety of skills necessary to maintain all shipboard equipment.’” (LCS Concept of Operations, p. 3) The crew and MP personnel on LCS will not have a large amount of time to conduct tasks that are not considered mission-essential. Any additional time needed by the crew or MP personnel is detrimental to the LCS mission.

c) Maximize Compliance Achievement—As stated in the introduction of this project, one key goal is to acquire compliance with the IUID policy as quickly as possible. Any excess time it takes to accomplish compliance is a lost opportunity for realizing total asset visibility.

d) Minimize Mistake Opportunities—Mistakes in data entry or procedures have detrimental effects on inventory visibility, as well as on the organization. Reducing mistakes results in quicker compliance with the IUID policy.

3. Define Measures

Measures help to determine how well each of the courses of action satisfies the goals. The cost measure is measured in dollars. Crew burden is measured by how much time is required of a member of the LCS crew or MP personnel. The following labels best describe the measure of compliance achievement: slow, slow-medium, medium, medium-fast, and fast. The mistake-opportunity measure is depicted by the following labels: low, medium, and high.[17] Each measure was determined from the process analysis conducted in Section C of this chapter, as well as from the research team's experience in Navy inventory management.

Table 8 shows the various measures for each course of action.

Course of Action	**Cost ($)**	**Crew Burden (mins)**	**Compliance Achievement***	**Opportunities for Mistakes**
Temporary Mark	1,039,500	7.6	Fast	High
Wait for Next Availability	0	0	Slow	Low
Electronic Transmission	1,039,500	9.1	Fast	Medium
Parts Marking Cart	3,389,500	7.6	Fast	High
Site Visits	333,960	0	Slow-Medium	Low
*Assumed after completion of training				

Table 8. Measure Definitions for Course of Action Decision

[17] Mistakes happening rarely are considered low opportunities for mistake.

Using LDW, the following is a screen shot of entering the cost measure:

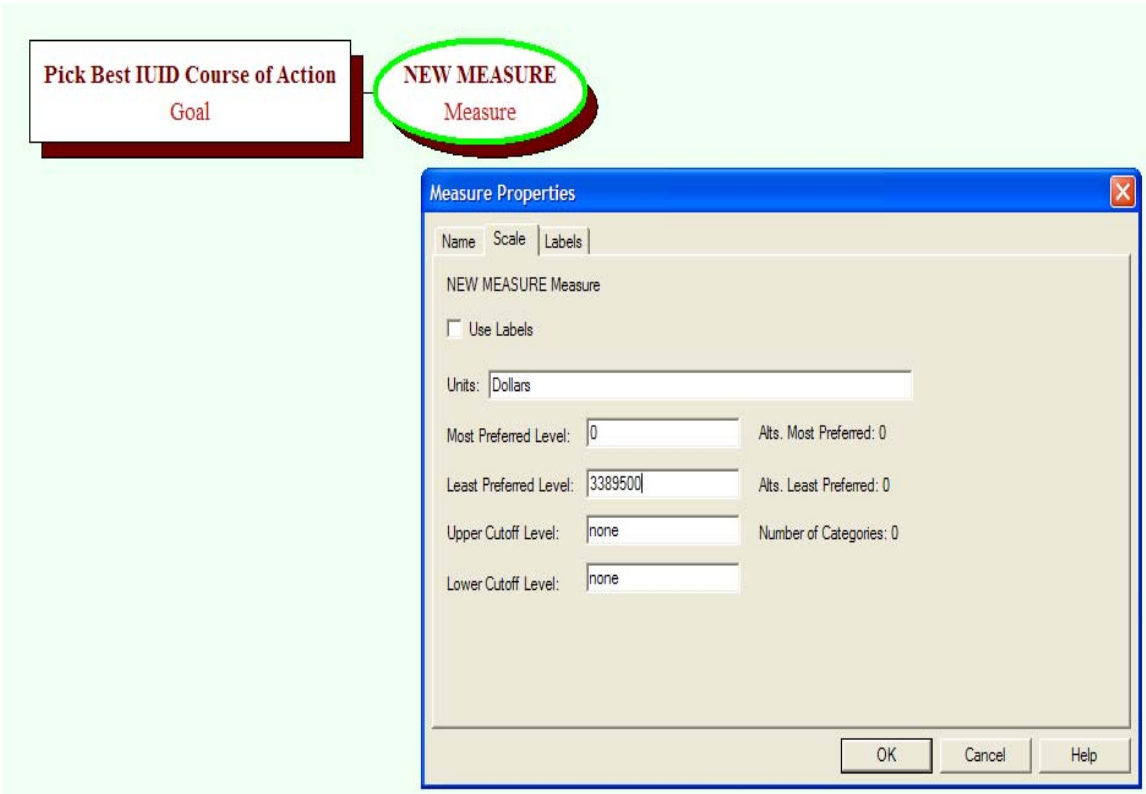

Figure 22. Price Measure Definition Using LDW

In the figure above, the most-preferred option in terms of cost was the one that had the least cost, which was zero. The least-preferred option was the one that carried the highest overall costs. This same method will be utilized for the crew burden measurement.

In order to define the measures requiring labels (Compliance Achievement and Opportunities for Mistakes), LDW allows inputs for this hierarchy of preferences. The following is a screen shot of inputting labels for the opportunities for mistakes measure.

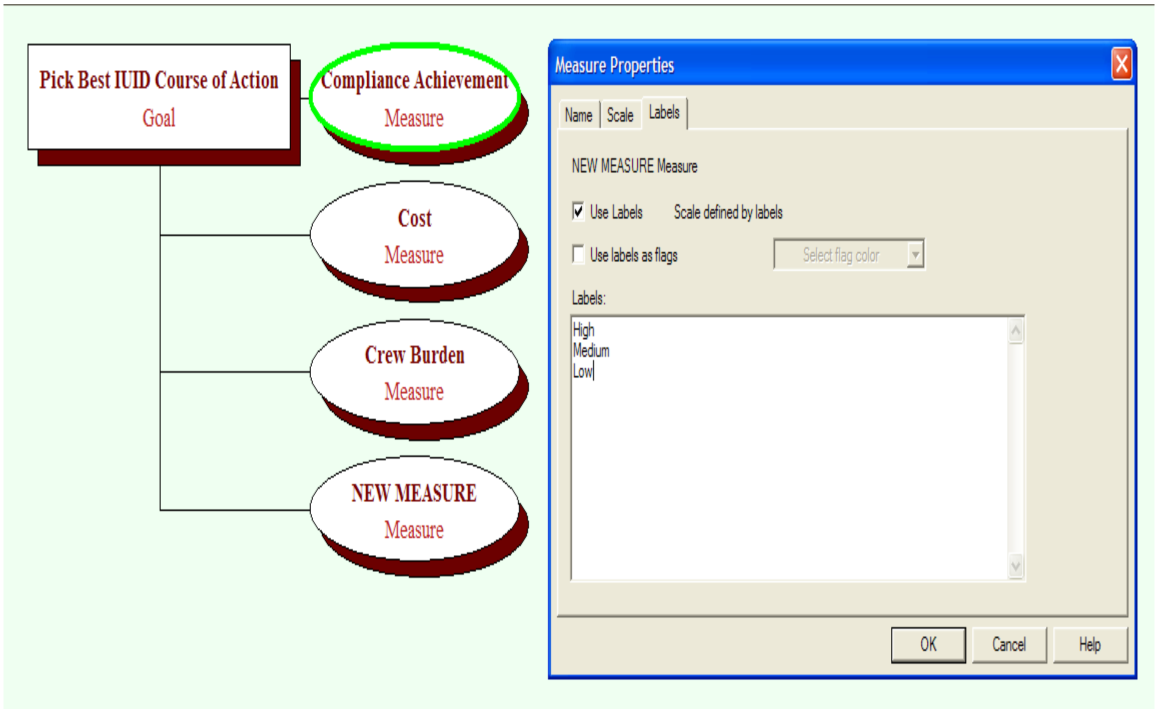

Figure 23. Opportunities for Mistakes Measure in LDW

Entering the definitions for the measures is conducted with the Matrix window of LDW.

Logical Decisions v. 6.2 - [Matrix: OVERALL Goal]

File Edit View Assess Review Results Preferences Matrix Window Help

	Compliance Achievement	Cost	Crew Burden	Opportunities for Mistakes
Electronic Transmission	Fast	1039500	9.1	Medium
Parts Marking Cart	Fast	3389500	7.6	High
Site Visits	Slow-Medium	333960	0	Low
Temporary Tag	Fast	1039500	7.6	High
Wait for Next Availability	Slow	0	0	Low

Figure 24. Measurement Data Entry in LDW

This figure is similar to Table 18, but produced in LDW.

4. Define Preferences

The next step in the analysis is to take the different measures and compare them to one another to convert the measures into common units. According to Logical Decisions®, "first, you define preferences concerning individual measures" and "then, you define preferences over goals—that is, weights—to combine the measures' common units into an overall score" (Logical Decisions®, p. 4–10). In addition, "LDW uses utility functions to combine the utilities of a goal's members into a utility (overall score) for the goal" (Logical Decisions®, p. 4–10). This is conducted using LDW's Single-measure Utility Function (SUF). Measures designated as the least-preferred level are assigned a zero, whereas measures designated as the most-preferred level are assigned a utility of one.

Due to the constraints of the minimal Logical Decisions®-manning concept, the SUF for crew burden dropped drastically as soon as any time was spent on a task not deemed mission-essential on the LCS. As a result, the following figure depicted the research team's assumption of crew burden.

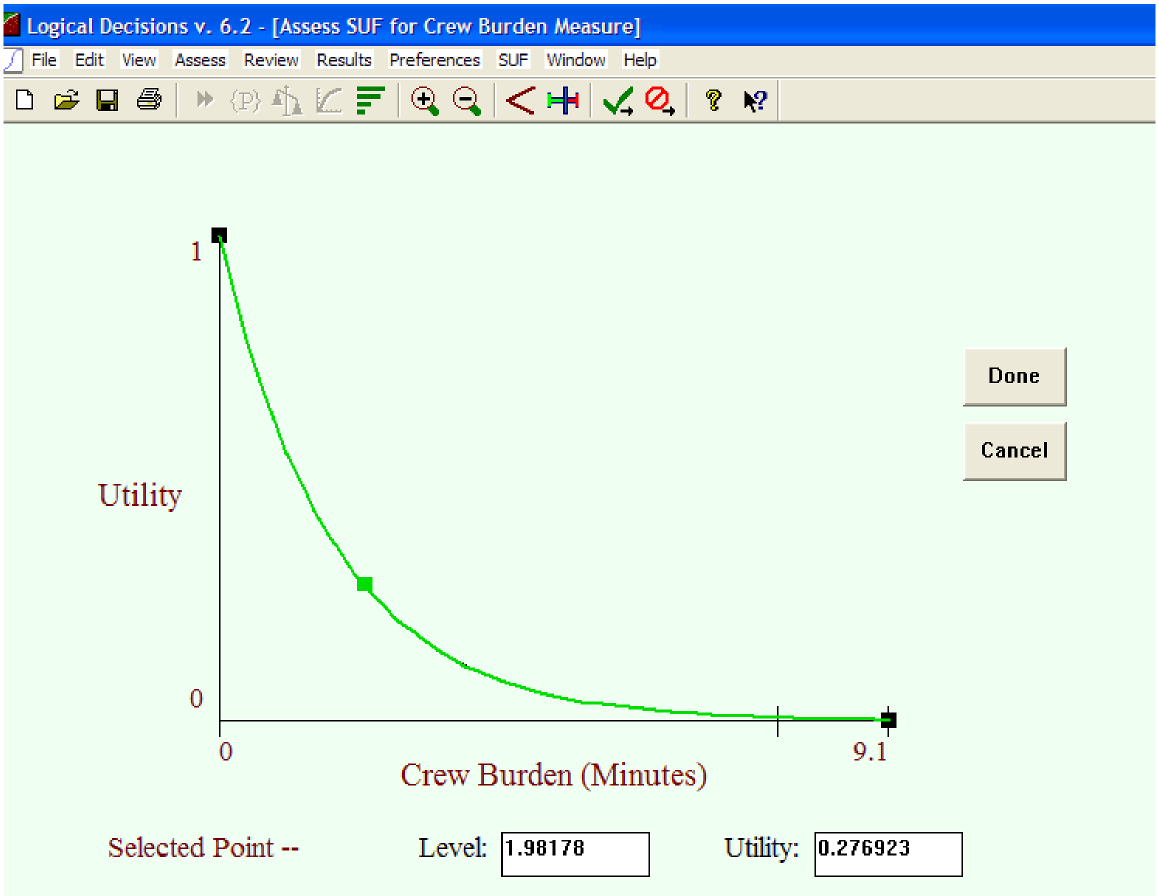

Figure 25. Research Team's Depiction of Crew Burden

Cost was assumed by the research team to be in line with a linear SUF.

Measures with labels follow a different approach to beginning the analysis. This approach is termed the "direct assessment method" (Logical Decisions®, 2010).

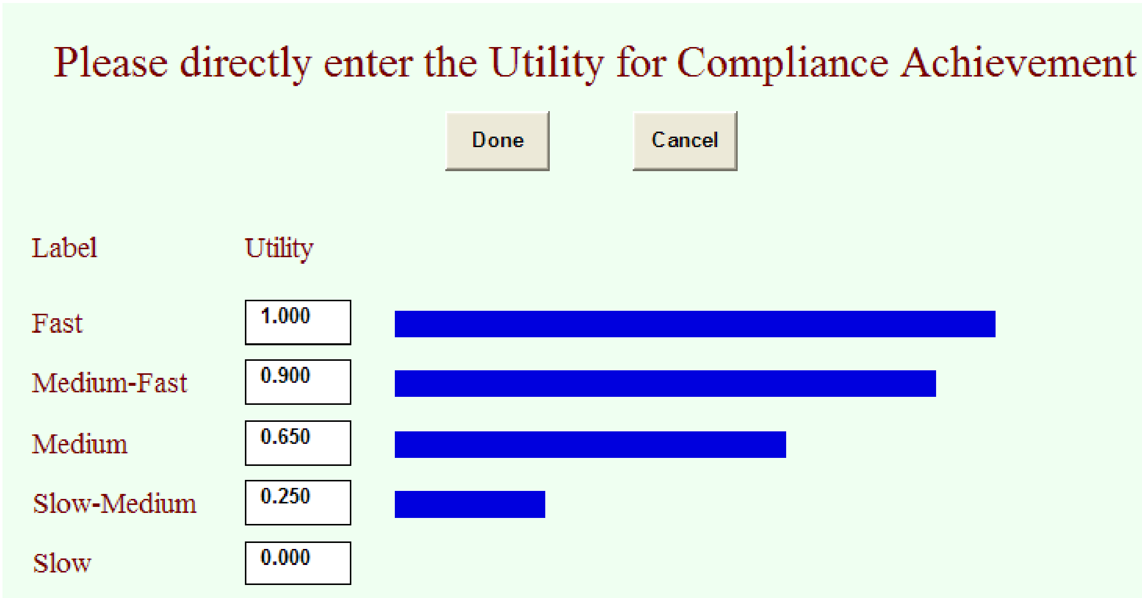

Figure 26. Direct Assessment Method of Compliance Achievement

The research team determined that any course of action that was of a slow or slow-medium speed was not as useful as a course of action that could provide at least a medium speed of compliance achievement. This direct assessment method was also utilized for the opportunities for mistakes measure.

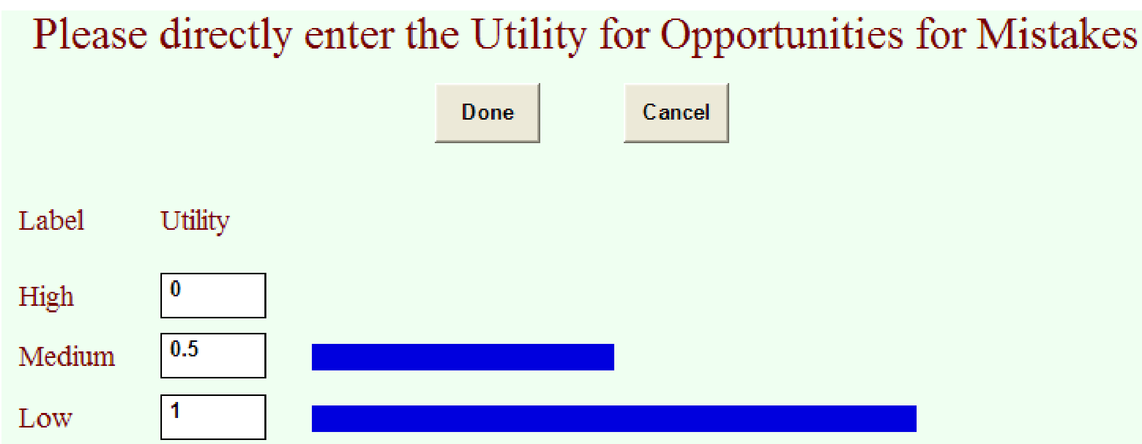

Figure 27. Direct Assessment Method for Opportunities for Mistakes Measure

A course of action providing a low opportunity for mistakes was more useful than a course of action that had more opportunities for mistakes.

5. Define Preferences Over Goals

The next part of the analysis involves assessing the relative importance of each measure as compared to another measure. This is termed a “tradeoff analysis” in LDW (Logical Decisions®, 2010). Figure 28 shows a tradeoff analysis between crew burden and cost.

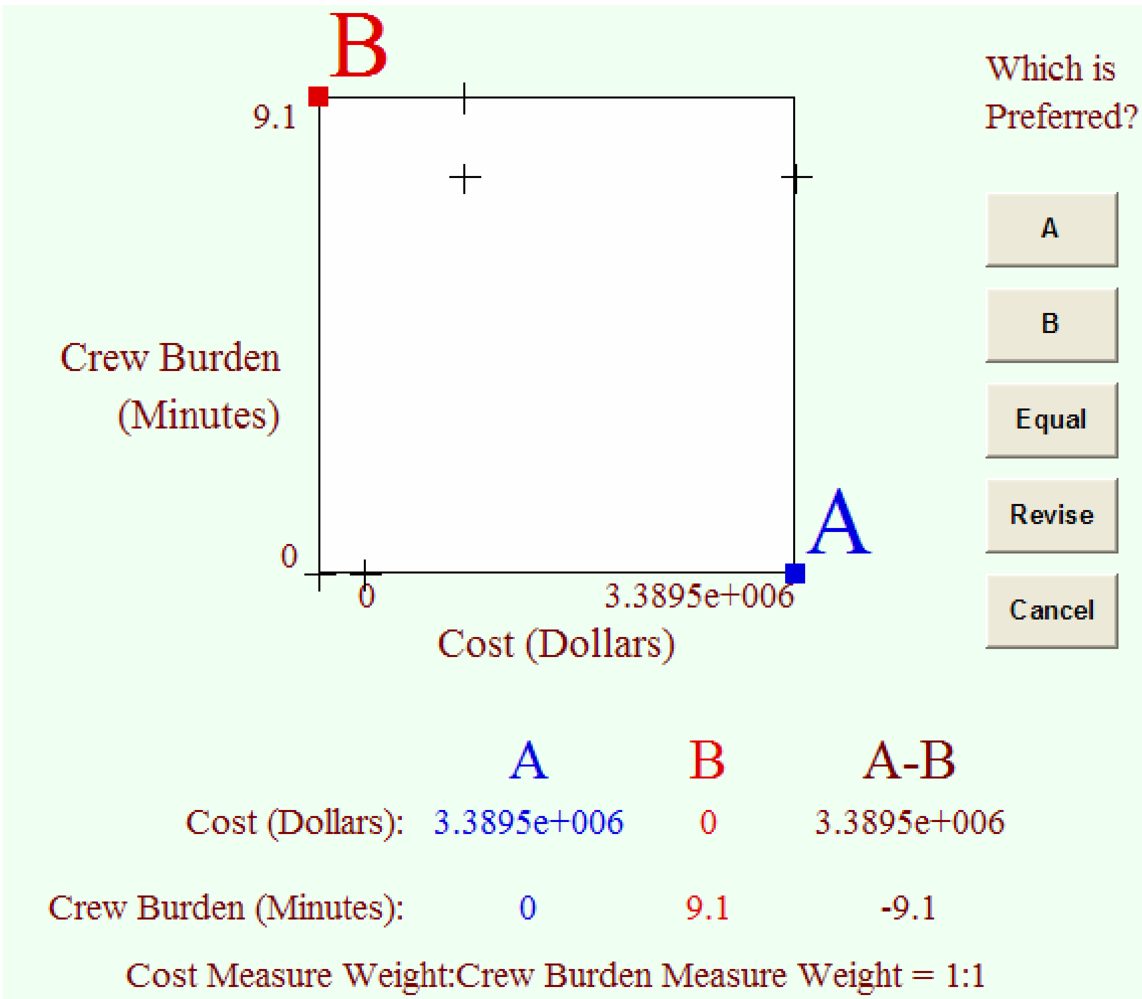

Figure 28. Tradeoff Analysis Between Cost and Crew Burden

With the tradeoff analysis, LDW asks which option is preferred: A or B. In this case, A is seen as a cost of $3,389,500 with a crew burden of zero minutes, and B is seen as a crew burden of 9.1 minutes with $0 for cost. The research team determined that crew burden outweighs even the highest cost to implement a course of action.

In the next step, LDW asks the operator of the program to pick a point on the crew burden axis where $0 and the choice for crew burden are equally preferred. Here, the research team determined that a crew burden of two minutes was equally preferred to a cost of $0, based on the assumed demands on personnel onboard the LCS, including the MP personnel.

For conducting the next sets of tradeoff analyses, the research team determined the following:

a) A fast speed of compliance achievement was determined to be equivalent to a cost of $1,117,800.[18]

b) A cost of $1,500,000 was determined to be equivalent to low occurrences for mistakes. There were no data to determine the effect of data-entry mistakes for IUID. The research team determined an estimate based on its past experience with manual inventory inaccuracies.

Once the tradeoff analysis was completed, a tradeoff summary graph was generated. Figure 29 displays the tradeoff summary graph. The circles indicate the proportion of that particular measure's weight. Lines connecting the circles indicate which measures were used during the tradeoff analysis (Logical Decisions®, 2010).

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[18] This is from the assumption that the amount of equipment for the SUW MM (455 line items) is equivalent to the amount of equipment in the other two MMs. If an inventory of the items is conducted quarterly, with an approximate time savings of 55 minutes for every 25 items inventoried, a labor rate of $25 per hour, the MPSF saves approximately $100,100 after 20 years for only three MMs and $3,970,000 over 20 years if the projected 64 MMs are procured. An average of the two figures amounts to $1,117,800.

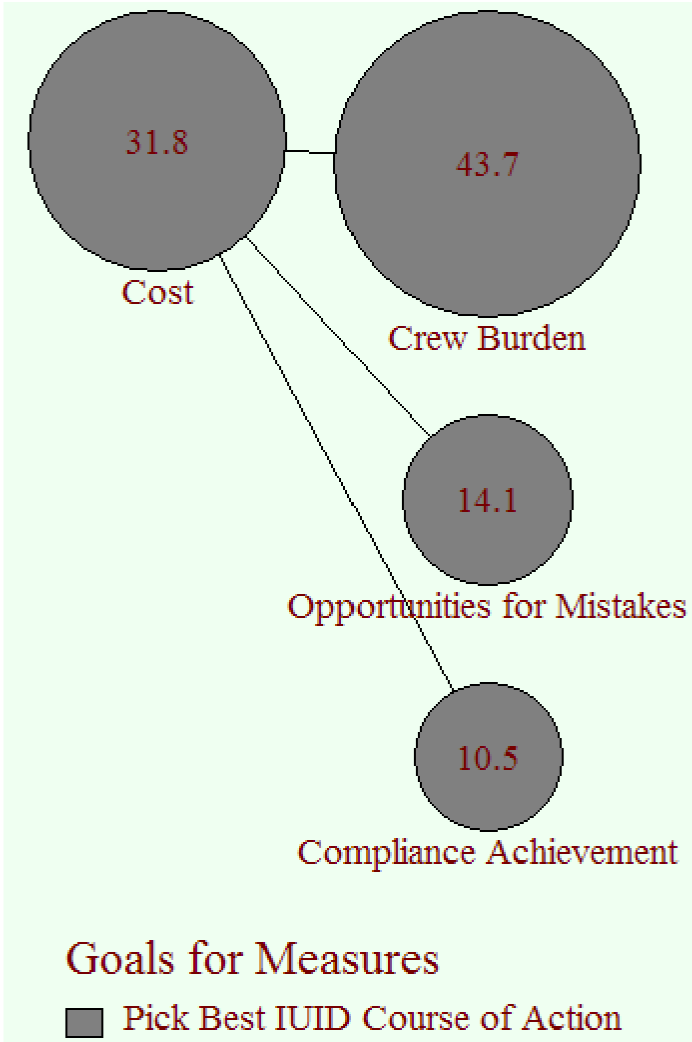

Figure 29. Tradeoff Summary Graph

Crew burden was determined to carry the heaviest weight when deciding on the course of action. In effect, the lower the crew burden for a course of action, the higher the possibility that the course of action would be chosen.

6. Course-of-Action Solution

The following figure displays the courses of action discussed in this project. The options are ranked with the highest utility option on top.

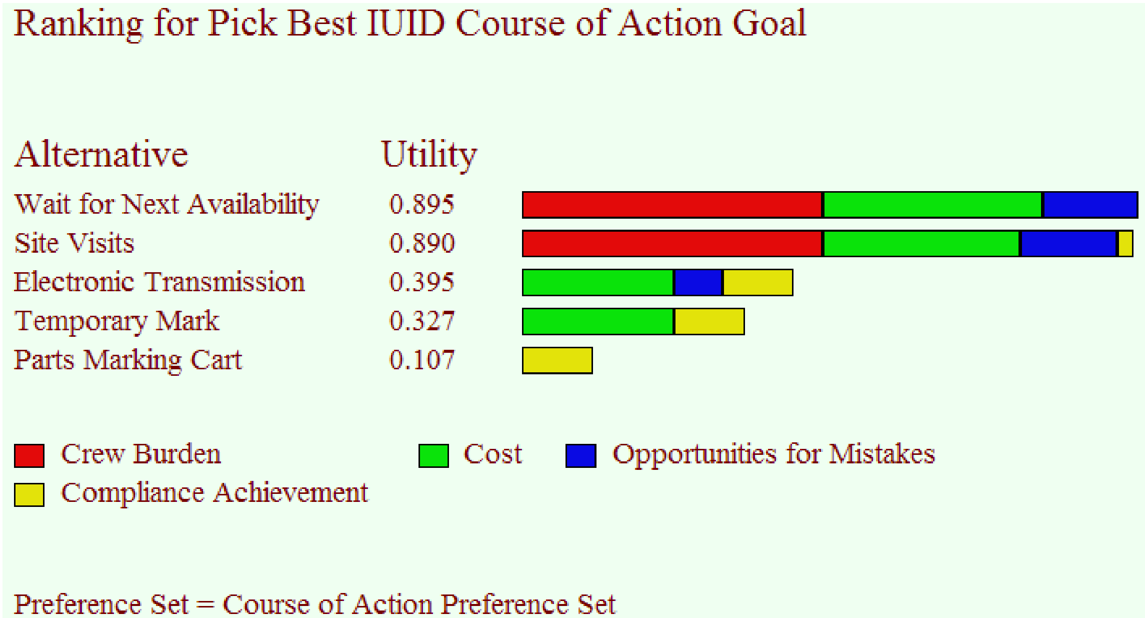

Figure 30. Course-of-Action Rankings

According to the final rankings, the best course of action to pursue is wait for next availability. The colors for each portion of Figure 30 represent the contribution that each measure made to the final utility of the alternatives. As stated before, the crew burden measure played a large role in the decision to wait for next availability, but it was the cost measure that overcame the site visit alternative. Even with a slight advantage in achieving compliance, waiting for the next availability still remains the course of action with the highest utility.

7. Sensitivity Analysis

Having determined the best course of action to pursue, a sensitivity analysis is required in order to provide a deeper understanding of how each of the measures played a role in the final decision.

Figure 31 shows how changing the weight of the cost measure would change the course of action. The vertical, black, solid line indicates the weight of the cost measure with the courses of action highlighted with their respective lines. If the cost measure's

weight had decreased to a little more than 25 percent, site visits would have been the chosen option. Any increase in the weight of the cost measure results in waiting for next availability as the chosen course of action.

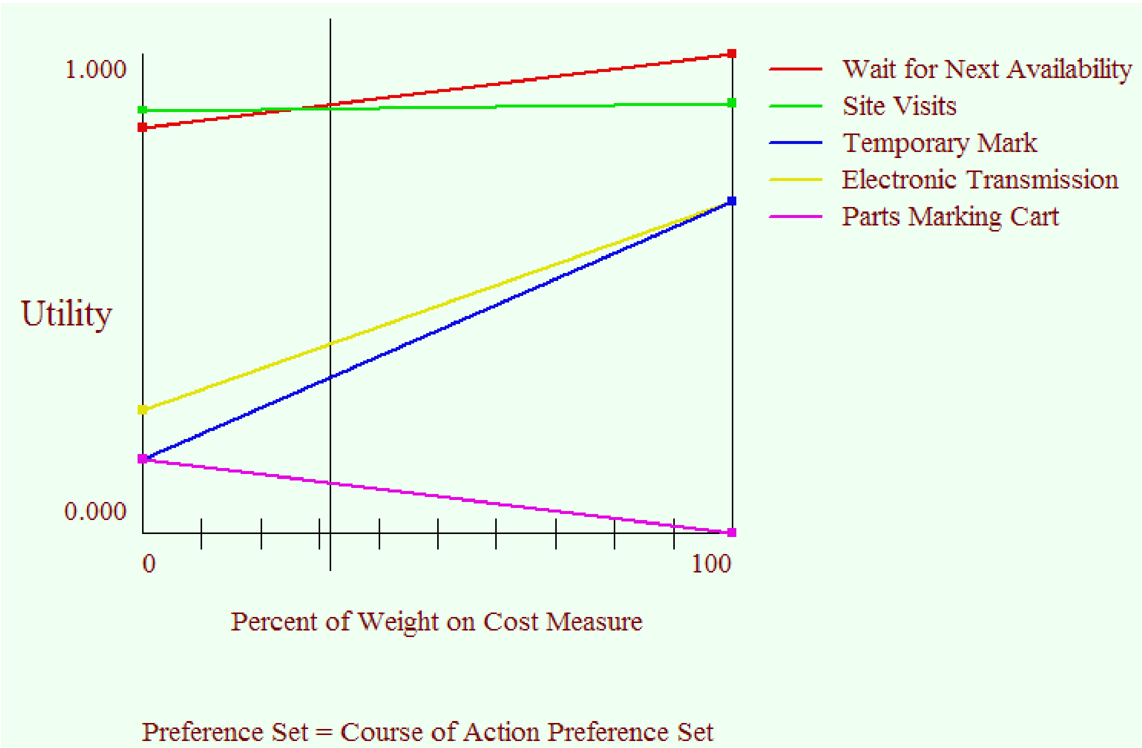

Figure 31. Sensitivity Analysis Based on Cost Measure

The next figure displays a sensitivity chart based on the compliance achievement measure. according to the figure, if the weight of compliance achievement been around 45 percent, the electronic transmission alternative would have been chosen.

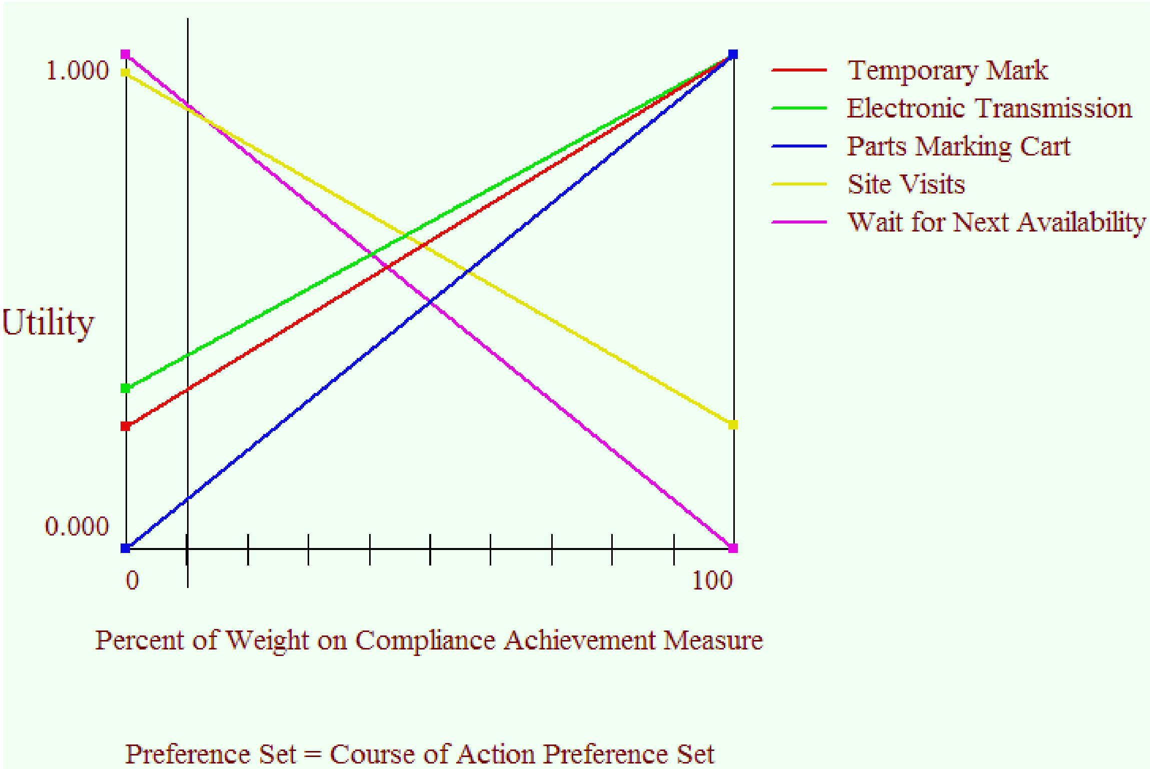

Figure 32. Sensitivity Chart Based on Compliance Achievement

If the weight had been increased about five percent, the site visits option would have been the selected course of action. An increase in the percent weight on compliance achievement measure results to above 45 percent would result in electronic transmission as the chosen alternative.

Another way of looking at the results is to compare the alternatives. the following figure depicts why the site visits alternative was not chosen.

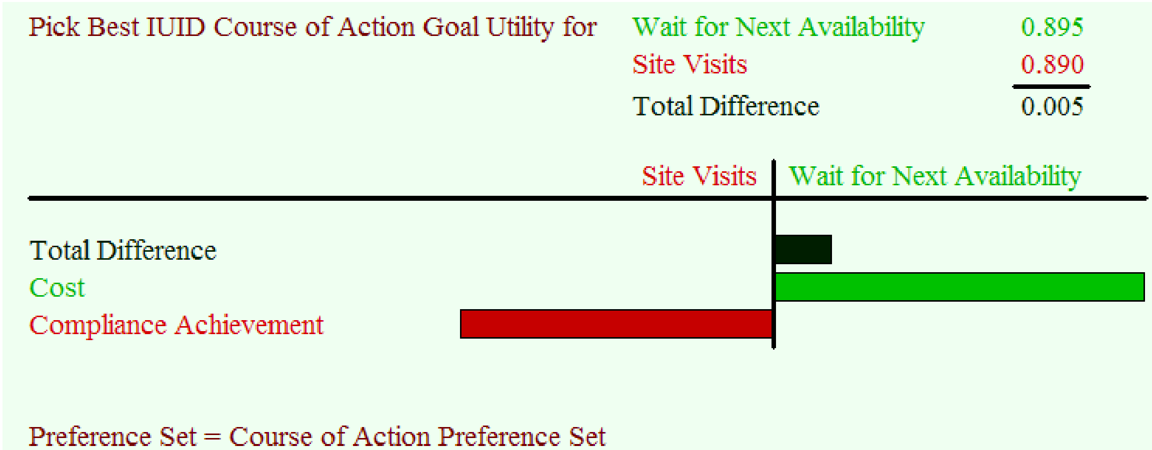

Figure 33. Site Visit and Wait for Next Availability Comparison

According to the figure, wait for next availability was better on the cost measure. the compliance achievement measure for site visits was better than for the wait for next availability, but the cost measure prevailed, even if its utility was only 0.005 greater.

VI. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. SUMMARY

The project started with an identification of the problem at the MPSF. Management at the MPSF, in addition to PMS 420, were interested in identifying strategies that would speed up compliance with DoD's IUID regulation but not carry hefty costs.

With the problem identified, the research team conducted thorough research on the history, the use, and the policies relating to DoD's policy memorandum regarding IUID. In addition, the LCS was discussed to provide background on the complexities revolving around the modular structure of its MP and, thus, its MMs. A discussion of the inner workings of the MPSF emphasized its IUID marking process.

Using the SUW MM as a basis for the analysis, an introduction into possible scenarios that would create the need to IUID an item was discussed. The following situations were mentioned:

1. Legacy items with a new need for marking (e.g., parts with higher-than-usual mean time between failures).
2. A direct requisition from an OEM that does not provide an IUID tag for its components that goes directly to the ship.
3. Equipment sent to an LCS logistics prepositioning site by an OEM that does not provide an IUID tag for its provided components.
4. The tag becomes damaged or is missing from the component.

This discussion led to the analysis of alternatives to remedy identified IUID need scenarios.

As part of the analysis, the research team examined the existing process flow for conducting an inventory with and without IUID in order to provide a justification for designing courses of action that would enable quicker achievement of IUID regulation compliance. The team came up with the following possible courses of action:

1. Having a parts-marking cart at each location (ship, prepositioned site, MPSF).
2. Use IUID temporary tags until the item is routed through the MPSF for permanent tagging.
3. Wait until equipment is brought to the MPSF during maintenance availabilities.
4. Use electronic transmission of IUID data for on-site marking.
5. Make site visits to LCS concentration areas (Mayport, Florida and San Diego, California).

Having made the argument for implementing IUID, the research team delved into a thorough analysis of the proposed courses of action in order to determine the proper criteria for making a decision.

The research team utilized Logical Decisions® for Windows in order to find an optimal solution to the problem presented by management at the MPSF.

B. CONCLUSION

Having run LDW to determine the best course of action, the research team found Waiting for the Next Maintenance Availability to be the best solution to handle the situations in which an item does not flow through the MPSF. Site Visits by MPSF was a close second, but ended up falling short. The main contributor to the decision was the need to utilize LCS crewmembers or MP personnel. Based on its minimal-manning concept, the LCS provides little room for extra tasks by a crew that is meant to perform every aspect of its mission with a severely reduced number of personnel (Douangaphaivong, 2004).

C. RECOMMENDATIONS

Although not the highest contributor to the final decision, costs associated with equipment investment and training could eventually become a leading contributor to the decision. At this time, with a limited number of MMs in operation, the other alternatives did not appear cost-effective to implement. But as the number of MMs in operation

grows, this could change, and implementing other courses of action would become more appealing. Further study should go into determining the point at which implementing a different strategy to ensure that items are IUID-compliant become cost-effective.

During the course of the analysis, the research team relied on its experience and expertise to determinate the necessary criteria. Having remained as impartial as possible, the research team recommends a survey of MPSF management personnel to determine their priorities with regard to implementing their IUID plan. The survey would provide a basis for implementing LDW in the decision-making process for equipment-investment decisions.

The research team also recommends a study into the contribution of IUID implementation to total asset visibility. In order to determine a true return on investment, it would be useful to assign a monetary value to total asset visibility and, thus, to determine how much IUID implementation contributes to total asset visibility.

Having mentioned prepositioning sites, but not including the amount in the analysis, a feasibility study is recommended to determine the best locations to place MM prepositioning sites.

Another recommendation for further research ties in with understanding the true cost of data-entry mistakes, how often these occur, and their effect on conducting an inventory.

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